



## Let's Look at the Balance Sheet!

ONCE A YEAR, at least, the average business man puts in a call for the auditor. Some one must take a look at the books and, after checking the facts and figures, certify those sacred symbols of finance known as the balance sheet and the profit-and-loss statement. The purpose of the former, we are cryptically informed by a banker friend, is to "tell you where you are," while the latter "tells you how you got there!"

But it has always seemed to us that the important thing about the balance sheet is that it shows both sides of the ledger—assets of various sorts balanced against liabilities of even wider variety. Too often in our enthusiasm for what has been accomplished we lose sight of the many problems still unsolved—the liabilities, if you will, that offset our assets of achievement. So, the thought occurred to us, why not take a technical audit of chemical engineering? Let's find where we stand in the technology of processes and equipment. In other words, let's look at the profession's balance sheet!

With this in mind, we called in the auditors. Half a hundred of them, skilled in the various unit operations and processes of chemical engineering, have prepared almost as many balance sheets, which, with their accompanying profit-and-loss statements, are presented for the first time in this issue of *Chem. & Met.* Another large group has cooperated in the preparation of almost fifty flow sheets—organization charts for chemical engineering in

industry. These are grouped in the editorial supplement of this issue, which is the second unit in the chemical engineering file promised *Chem. & Met.* readers last January.

The whole is presented by editors and contributors with a three-fold purpose:

1. To encourage chemical engineers in every industry to make a technical audit of their present status and thereby to learn what is needed to bring their plants and processes to the highest known standards of production efficiency.
2. To encourage those in research and development work to direct their efforts toward filling in, with needed data and information, the many gaps existing in our present theoretical knowledge.
3. To encourage those who see in chemical engineering the making of a truly great profession once our efforts are coordinated in applying our knowledge and data for the benefit of chemical engineers as well as chemical engineering.

All three of these objectives are worth while, but we hope we may be forgiven for repeating here that our major concern remains with the profession. Its balance sheet reveals many shortcomings which can be corrected only when we are willing to face the facts, unpleasant as well as pleasant. So let's make this audit of technology a start toward the much more important appraisal of our true worth to industry, to the community and to ourselves.



# CHEMICAL ENGINEERING

## ASSETS AND

**EDITOR'S NOTE:** Dr. Perry has had the unusual and fortunate privilege of being associated during the past few years with a group of the outstanding leaders in the theory and practical application of the unit operations of chemical engineering. These contacts have revealed many brilliant accomplishments, but have also disclosed, sometimes by strong and startling contrast, some of the shortcomings of our profession. It was at his suggestion and with his helpful support and criticism that "Chem. & Met." undertook to prepare a technical balance sheet of chemical engineering. The individual unit operations and processes have been "audited" and are reported in balance sheet form elsewhere in this issue, largely by the group of specialists who were associated with Dr. Perry in the preparation of the "Chemical Engineers' Handbook." The introductory article which follows deals with some of the general but important needs of the profession.

**O**UR PRESENT KNOWLEDGE, both theoretical and practical, of the unit operations of chemical engineering is far from satisfactory, even though we "get along" and even though our detailed knowledge has increased very materially during the past decade or so. In some fields we are more fortunate than in others, but for a few unit operations, our theoretical knowledge is nearly zero and our practical knowledge is entirely empirical. Even the latter is sometimes woefully inadequate simply because we do not have at hand an accurate and practical measure of performance. The purpose of this article is to attempt to outline what is believed to be the general, as well as a few of the more specific, needs of the chemical engineering profession.

It would seem to be generally agreed that the most pressing present requirements are those directly applicable to the actual operation of plants, processes and equipment. These needs are particularly critical as regards operating information and data for existing types of equipment. Such required information should include methods of operation to give greater efficiency and control, as well as greater flexibility in more readily producing materials of desired properties. There is also need for new types of equipment in the many processes where the existing types are really little more than makeshifts or at best are extremely inefficient.

**Plant Location.** Great stress has properly been given to the unit *physical* operations of chemical engineering, such as fluid flow, heat transmission and distillation. There has also been a definite increase and more active interest of late in the further scientific development of the unit *chemical* processes such as nitration, sulphonation and chlorination. With this increased interest, however, there would seem to be an imperative need for the practical development and crystallization of the aims, principles, functions and characteristics of plant loca-

tions. This is neither a unit operation nor a unit process but it deserves a separate niche in the classification and development of the tools of industry. Geographic location is of paramount importance to almost every chemical or process industry. The plant process may have been fully developed with regard to production capacity and technical efficiency, but is doomed to failure unless its economic efficiency is assured. One of the first and most important links in the chain of economic efficiency is that of plant location.

An attempt to initiate and to catalyze the development of a science of plant location must, we believe, be prefaced by a review of the material available in the existing literature, and by an attempt to evaluate properly all of the pertinent factors and their inter-relationships. Later a collection and correlation of the data and information that are necessary for an intelligent study of the more general types of problems in plant location should be made. Only after these preliminary studies can it be hoped that a sufficiently thorough and stable foundation will have been laid on which to build the scientific development of plant location to the point of real usefulness to industry and to technical men.

A review of the literature of plant location discloses that while much has been written on the more general aspects of the subject, there is an astonishingly small percentage of published material that is of immediate or specific value. A great deal of the available literature is composed of industrial surveys, many of which are quite plainly propaganda for the development of certain cities or sections of the United States. These surveys contain many items of value although they should be analyzed carefully before definite and practical use is made of the data or other information given.

An effort is now being made to collect and correlate a bibliography on plant location and to prepare a survey of the historical development of the subject in order to

# LIABILITIES

By JOHN H. PERRY

*Editor-in-Chief, Chemical Engineers' Handbook, Chemical Engineer, E. I. du Pont de Nemours & Co., Inc. (Grasselli Chemical Co., Cleveland, Ohio)*



indicate clearly the important factors in the problem of modern plant location. It is hoped that such an article will be a helpful start in a thorough attempt to develop this subject into a real and useful tool for the chemical engineer. (Editor's Note: Later in the year *Chem. & Met.* proposes to devote an entire issue to plant location in relation to recent industrial developments throughout the South and Southwest).

**Plant Design.** The subject of plant design, like that of plant location, is neither a unit operation nor a unit process. Its readily admitted importance in the development of a technically and economically efficient plant process indicates the necessity for a separate and prominent place in any accurate classification of the tools of our profession. The detailed needs cannot be exhaustively analyzed here, but we can stress in a few words the first necessity for a well-considered survey and analysis of the principles and chief factors in plant design.

A careful application of the accurate principles and data of the unit operations to a given plant process may be largely a waste of time if the design of the plant does not include consideration of such factors as the time, power, and total cost of moving materials; the availability of the plant services such as steam, electricity and air; the arrangement of individual equipment from the standpoint of the efficient routing of materials in process as regards both the efficient use of the individual equipment and the use of the labor required; potential hazards and means of accident prevention; fire protection, etc.

Under plant design there should also be stressed the need for a more complete evolution, analysis and standardization of the means for the transition or translation of processes through the well-known stages of laboratory development to semi-works or pilot plant and finally to

As many others who in recent years have contributed markedly to the advance of chemical engineering, Dr. Perry received much of his graduate training from the Massachusetts Institute of Technology, which awarded him his Ph.D. degree in 1922. His undergraduate work had been done in the university of his native state of Maine, in which he was born November 10, 1895. He attended Northwestern in 1919-20 and earned his M.S. degree while serving as a graduate assistant. His industrial and professional experience has been gained with the American Agricultural Chemical Co., the Ordnance Dept. of the U. S. Army, the U. S. Bureau of Mines and, since 1925, with the du Pont company.

large-scale commercial operation. (Editor's Note: A textbook on plant design is now being prepared for the Chemical Engineering Series by Prof. F. C. Vilbrandt of Iowa State College.)

**Needed Data.** The availability of the existing physical and chemical data may be regarded as satisfactory perhaps when the major portion of such data are considered. However, the unpublished data (or those which exist only in obscure or difficult-to-find journals) or information now in the files of individuals and private corporations could usually be made public without detriment to those corporations or individuals. This might be done through published articles, or through a central correlating committee of a recognized professional group. Many progressive firms have contributed and are contributing very freely of the data and information obtained in their operations and researches. Such liberal policies of publication are very frequently due to a realization of the debt to the profession owed by such industries. Much less frequently, these policies may be due to an appreciation of the knowledge that one firm's example will be instrumental in causing other firms to initiate similar publication policies. In spite of the large amount



of data and information that these and other companies publish, it is conservative to state that only a very small fraction of that now in the files of corporations and individuals is as yet available.

In connection with our present lack of data and information, it is appropriate to point out the unwillingness of many technical men to publish isolated data unless their facts support a new theory or an extension of an old theory. This attitude should be discouraged and definite efforts made to stimulate the publication of all pertinent information. At the same time, it should be remembered that our chemical and chemical engineering journals can scarcely keep pace now with the demands of the many manuscripts submitted to them. Possibly a committee would be the proper focal point to collect such data and either annually or semi-annually coordinate them for publication. In no other way will much of this information be made available for general use.

**Bibliographies.** The need for carefully compiled bibliographies of each of the unit operations and unit processes of chemical engineering cannot be overemphasized. Complete and accurate bibliographies of the existing patent literature would be of incalculable value to the chemical industry and would be of great assistance to patent examiners and to the Courts in which costly and time-consuming patent litigation is in progress.

Complete bibliographies of articles and patent literature of the following unit operations of chemical engineering, or one of their sub-divisions, are now being collected and correlated: distillation; evaporation; crushing, grinding, pulverizing, shredding and comminution in general; drying; humidification, dehumidification, cooling towers and spray ponds; crystallization; screening, tabling, sizing and sifting; sampling; and filtration. A great deal of progress is known to have been made to date in the preparation of these bibliographies, particularly in the case of distillation (and its sub-divisions of liquefaction, condensation, etc.) which is nearly completed. Those for evaporation, drying, crushing and grinding, crystallization and filtration are well advanced.

**Treatises.** Preparation of true treatises of the individual unit operations of chemical engineering is a very large task, and, to be of optimum value and completely authoritative, each should be prepared under the editorship of an expert who has a broad knowledge of the field and can extend a guiding hand to a group of co-operating authors. Each unit operation is now too diversified to enable one man or even two or three men to prepare a suitably thorough comprehensive and authoritative work. At least eight or ten contributing author-specialists would seem to be required for most of such individual treatises of the unit operations. Each of such contributing authors should have not only a broad knowledge of the particular unit operation involved but, in addition, should be a sort of a super-specialist in some sub-division of that unit operation. For example, a contributing author of a treatise on Crushing and Grinding, should not only have a broad knowledge of the entire unit operation but should be especially familiar and expert in, say, the comminution of (a) coal, (b) phosphate rock, or (c) fibrous materials, or some other sub-division of the unit operation of comminution.

**Histories.** The value of the history of a division of science or engineering to its rate of development is not always evident, but a knowledge of what has gone before can usually expedite the progress of knowledge in a particular subject. Some of the reasons for this are: (a) avoidance of duplication of work already done; (b) knowledge of the history of equipment, for example, indicates trends in the evolution or development; (c) avoidance of the expenditure of time and money for the development of equipment and processes, the main feature of which in many cases may have already been known hitherto; and (d) the avoidance of useless (valueless) patent applications which would thus help to relieve the present flooded condition of the patent offices of the world.

**Technical Graduates.** Whether the technical graduate is regarded as a "finished product" of a school, as an "intermediate product," or as a "raw material" of industry, his "properties" are far more inconstant than would ever be tolerated in the usual raw materials or finished products of a manufacturing enterprise. The reasons for such inconstancy are, it is true, due in a large measure to the human element or the personal equation of both students and teachers, but it is believed that other reasons that are more controllable may well be the causes of many of our difficulties.

It is further believed that a thorough analysis of the present average graduate and of the "processing methods" used in his production by both the true producers (pedagogues) and by the users (industrialists) could not fail to improve the present "product" even though it must be admitted that today's chemical engineering graduates are a vast improvement over those of earlier years. While it is not possible here to make a complete and entirely satisfactory audit of the assets and liabilities of chemical engineering education, it is most desirable that an accurate balance sheet be considered. Such a task can be accomplished satisfactorily only by the combined efforts of teachers and industrialists—carrying a step farther the commendable work of the Institute's committee on chemical engineering education.

**What's To Be Done?** How can the liabilities of chemical engineering be converted into assets? Elsewhere in this issue the major unit operations and unit processes of chemical engineering have been reviewed and a balance struck in each instance. In other words, the first principles of the operation of a commercial undertaking have been applied to the analysis of our present status as a profession—we have made an accountant's audit of our technical status. Similar and more extensive audits should be made of our condition at frequent intervals. Also there would seem to be every reason why we should continue to apply the principles, methods and organization of a business to our major problem of converting our present liabilities into assets. Is it not possible to organize and program our needs by the same methods and with the same expedition that is given to business problems by industrial management? Application of such principles will at least start us on the road leading to valuable dividends of data and other needed information that should markedly increase our business ratio of assets to liabilities.



# A NEW CLASSIFICATION OF UNIT OPERATIONS

By THEODORE R. OLIVE

Associate Editor  
Chem. & Met.

**D**URING the past 25 years, or thereabouts, while chemical engineering has been attaining full stature as a distinct branch of engineering science, a conception of the *unit* character of chemical industry's operations has gained wide acceptance. To a greater and greater extent throughout this period, chemical engineering training has been based on this conception, and practicing engineers have come to employ it constantly in their daily work. Various classifications of the unit operations have been proposed and put into use, one of the earliest of which was developed by *Chem. & Met.* and since used in modified form by most writers on the subject.

Now, however, that an appraisal of the unit operations is to be made, it seems appropriate to attempt a new classification, designed to overcome some of the shortcomings of the old. It is not the writer's purpose to suggest a hard and fast pattern wherein the unit operations of chemical engineering must be made to fit, nor to imply that the chart which appears on the following page is either exhaustive or incapable of improvement. None the less, it has been his feeling that a grouping could be developed which would be helpful to practicing engineers, which would assist clearer thinking and bring about a better conception of interrelations. In combination, therefore, with the individual appraisals of unit operations which make up the later pages of this issue, the chart, it is hoped, will open avenues for improved technique which previously may have been obscured by the greater compactness of earlier classification schemes.

Before going into a description of the new classification it may be worth while to distinguish between the *unit operations* and the *unit processes* of chemical engineering. For many years the latter term was used interchangeably with the former, but quite recently it has taken on a special and distinct meaning. As generally employed, "unit operation" now means any mechanical or physical operation of unit nature, used to condition one or more of the reacting materials in a technical process or to control their environment. Unit operations bring about changes of state, of position, or of energy content, but they do not affect chemical constitution or molecular structure.

"Unit processes," on the other hand, have been defined by Groggins as representing the embodiment of all factors in the technical application of individual reactions. Chemical change, rather than physical or mechanical, is the distinguishing characteristic of unit operations. But it is to be noted that the two unit procedures are interrelated at every turn, for no reaction nor series of

reactions can be employed commercially without the application of one or more unit operations.

In arriving at any sort of scheme of classification it is helpful to employ a method of logic inherent in the science to be classified. Such a logical scheme is immediately apparent when one attempts to jot down and then reduce to fundamentals the several sorts of procedure, aside from reactions, in any technical process:

Materials are involved and these materials must be brought to the process and carried through it. Fundamentally, this operation is "materials movement," but since the handling of solids and semi-solids differs so radically from that of liquids and gases, a separation to the two seems worth while. Two elementary operations of movement: *materials handling* (solids and semi-solids) and *fluids handling* (gases, liquids and vapors) will, therefore, serve to start our list.

Particle size is extremely important, both in its effect on intimacy of contact during reaction and as a means of conditioning the finished product to the demands of trade. *Disintegration* (and much less frequently the converse) is our next elementary operation, to which is closely allied *mixing*, to secure the distribution and contact required by the process. Once the materials are in optimum relation with each other, satisfactory progress of the reaction can be obtained only by control of the energy level of the reactants and this may demand the addition or removal of heat—*heat transfer*.

Either during the reaction or at some other stage in the process, certain components must be removed from the vicinity of others, or some portions of one material (fines and oversize, for example) must be separated from the remainder. Water or solvents must be abstracted, products of side reactions segregated and other like operations accomplished. All of these are operations of *separation*, which then becomes our sixth elementary procedure.

One or more of a small group of miscellaneous operations of a purely physical nature may also enter into the process, but still defy classification. These encompass such effects as changes in colloidal state, change in pressure, and conditioning by means of a catalyzer which, without taking part in the reaction, can still hasten it.

Finally, all of the fundamental procedures listed above will require control. Quantity of flow, energy content and many other factors must be held within desired limits if the ultimate product is to meet specifications. *Control* is, therefore, the last and one of the most fundamental of this group of elementary procedures.

No process has occurred to the writer in which is an operation that cannot be covered by one of these eight groups. If fluids and solids are moved through the process and brought to the desired size and intimacy of contact; if their energy level is held at the desired point and separations are affected as needed; if such physical conditions as colloidal state and intermolecular distance are adjusted, and if all these operations are so performed as to give optimum results, then every contingency within the process, except the purely chemical, has been covered.

So far, so good, but the problem of a strictly logical choice of the contents of each of the eight boxes is not so simple. In the case of separation, for example, every

## Classification

## Unit Operations

## Equipment

## MATERIALS HANDLING

## FLUIDS HANDLING

## Proposed Classification of

## Chemical Engineering Unit Operations

## And Equipment

## MIXING

## HEAT TRANSFER

## Conduction

## Convection

## Radiation

## Heating

## Cooling

## Evaporative

## Solution†

## Vaporization†

## Filtration

## Non-hydraulic settling

## Water concentration

## Gravity settling

## Measuring

## Controlling

## Physical

## Electrical

## Mechanical

## SEPARATION

## Resistance

## Differential settling

## Settling and decanting

## CONTROL

## Physical Operations

## (Misc.)

## Also heat from other reactions.

## †These operations generally but not necessarily used for separation.

## ‡Probably phase change with most gases and vapors.

Gathering.....	Cranes, drag lines, industrial cars, pneumatic conveyors, car dumpers, power and hand trucks, stackers, skids
Storing.....	Bins, hoppers, sheds, barrels, open storage, silos, stackers
Transporting.....	Automobile trucks, industrial cars, Dry-Plo cars, barrels, drums, keps, power and hand trucks, skids, box and gondola cars
Conveying.....	Belt, screws, elevators, bucket and pallet conveyors, Redlers, solids pumps, pneumatic, flight and vibrating conveyors
Gravity flowing.....	Piping, flumes, conduits, valves, fittings
Pneumatic pumping.....	Plunger, piston and rotary pumps, pulsometers, blow cases, air lifts, screw pumps, piston compressors, pipe lines
Kinetic pumping.....	Centrifugal and turbine pumps and compressors, fans, blowers, jets, pipe lines
Crushing.....	Jaw crushers, gyrators, disk crushers, Hadied mills, rolls
Grinding.....	Ball and hammer mills, rolls, ring-roll mills, cage mills, chasers
Pulverizing.....	Hammer and attrition mills, griststones
Shredding.....	Hogs, chippers
Chipping.....	Masticators
Smelting.....	Spray nozzles, turbine-type dispersers, pumps, piping, valves, spray chambers
Mixing.....	Chasers, flight and screw mixers, tumbling barrels, ballstone mills, roller mills, ball mills, turbine, paddle and propeller mixers, coating pans
Agitating.....	Turbine, propeller and paddle mixers, air-lift and air-bubble agitators, pumps, compressors
Knading.....	Rolls, double-arm mixers, chasers, epicyclic chasers (Lancaster)
Emulsifying.....	Turbine, paddle and propeller mixers, colloid mills, homogenizers, pumps
Dispensing.....	Turbine, paddle and propeller mixers, colloid mills, homogenizers, pumps
Diffusing.....	Tanks, vats, diffusion cells, pumps
Direct heating.....	Electric arc, resistance and induction furnaces, fuel-fired furnaces, kilns, muffles, etc. (heating by radiation and furnace gases)
Indirect heating.....	Heat exchangers, furnaces, etc., used to supply heating medium such as hot air, water or oil, or vapors such as steam, mercury, diphenyl, D.P.O., etc
Air cooling.....	Heat exchangers, condensers, cement coolers, waste-heat boilers, preheaters
Water cooling.....	Condensers, diesel, refrigerating equipment, process coolers
Ice cooling.....	Process vessels
Spray cooling.....	Spray ponds, cooling towers
Refrigerating.....	Steam jet units, centrifugal vapor units, compression and absorption units
Leaching.....	Tanks, vats, Pachuca and Shanks tanks, classifiers, ball, tube and stamp mills, pumps
Dissolving.....	Tanks, vats, agitators, pumps
Extracting.....	Tanks, vats, classifiers, diffusion cells, agitators, gas equipment, pumps
Percolating.....	Percolators (solvent circulated), pumps
Washing.....	Tanks, agitators, classifiers, thickeners, filters, centrifugals
Gas absorbing.....	Packed towers, spray chambers, bubble and plate towers, Woulff bottles, tourills, blowers, exhausters, pumps
Crystallizing.....	Ponds, vats, agitators, agitated troughs, rotary and rocking crystallizers, salting evaporators, vacuum crystallizers, grainers
Condensing.....	Heat exchangers, condenser, rotary and rocking crystallizers, salting evaporators, vacuum crystallizers, fractionating columns, pumps
Distilling.....	Pot and surface condensers, spray chambers, heat exchangers, fractionating columns, pumps
Evaporating.....	Let and pipe stills, packed, bubble and plate columns, pumps, condensers, separators
Drying.....	Tanks and kettles, atmospheric and vacuum evaporators (single and multiple effect), film and forced-circulation evaporators, water stills
Subliming.....	Atmospheric and vacuum dryers, tunnel, truck, pan and tray dryers, conveyor dryers, rotary, drum and festoon dryers
Melting.....	Retorts, condensing chambers
Frothing.....	Furnaces, kettles, crucibles, reaction equipment
Absorbing.....	Molds, solid CO <sub>2</sub> presses, refrigeration equipment
Magnetic separating.....	Char and contact filters, false bottom and agitated tanks, packed towers, activated carbon, silica gel and other adsorbents
Electrostatic separating.....	Magnets (permanent and electro), magnetic pulleys and chutes, high-intensity separators
Electrophoresis.....	Huff separator, Cottrell precipitator
Gravity filtering.....	Clay extruding machinery (only present known commercial application)
Vacuum filtering.....	Slow sand filters, false-bottom tanks, Hardinge clarifier, Laughlin thickener, nutches
Centrifugal filtering.....	Rapid sand filters, clarifiers, filter presses, leaf filters, continuous filter presses (Thompson)
Screening.....	Rapid sand filters, disk filters, leaf filters, drum-type filters, Dorco filter, filter-type thickeners, savalls, nutches
Sieving and bolting.....	Continuous, semi-continuous and batch centrifugals with perforated baskets
Pressing.....	Grizzlies, trommels, gyrating, shaking and vibrating screens
Flotation.....	Sieves, sifters, bolters (rotary, shaking, vibrating), turbine sifters
Classifying.....	Hydraulic and mechanical presses, curb presses, expellers, continuous filter presses (Thompson)
Chamber (basin) settling.....	Draining decks, screens, classifiers, tables, dewaterers, filters, centrifugal filters, nutches
Air separating.....	Reciprocating and spiral rake classifiers, bowl and drum classifiers, hydraulic cones, multiple-spigot classifiers
Jigging.....	Settling basins, dust chambers (void, chain-filled, shelled), Spitzkasten
Tabling.....	Equipment employing change of air direction, velocity, or both, i.e., cyclones, Multiclones, vacuum, fan and dynamic-type separators
Vanner separating.....	Hydraulic jigs
Dialyzing.....	Concentrating tables
Gas diffusing.....	Vanners
Impinging.....	Animal membranes, vegetable parchment, cellulose film; used as bags or as diaphragms
Settling and decanting.....	Porous plates (unavoidable diffusion of certain gases through metals at high temperatures)
Gravity settling.....	Air and gas washers, entrainment separators, spray chambers, air and gas filters (wetted or oiled surface), P & A 'ar extractor
Measuring.....	Settling basins, tanks, vats, thickeners
Controlling.....	Settling tanks with multiple or swing draw-off pipes
Physical Operations (Misc.).....	Continuous, semi-continuous (Rotofactor), and batch centrifugals and centrifuges with solid baskets, cyclones
Also heat from other reactions.....	Automatic samplers, manual samplers, "thieves," "Samplitt"
†These operations generally but not necessarily used for separation.....	Thermometers, flowmeters, electrical instruments, gravity and density meters, scales, etc.
‡Probably phase change with most gases and vapors.....	Flowmeters, flowmeters, electrical instruments, gravity and density meters, scales, etc.

• Also heat from other reactions.

†These operations generally but not necessarily used for separation.

‡Probably phase change with most gases and vapors.

important method of separation should be dropped into its proper niche, but only when it is certain that the method is actually a unit, i. e., incapable of being broken down into two or more sorts of separation. Thickening by this definition is not a unit operation for it combines both settling and decanting. Yet for practical reasons, settling and decanting should be kept together, since no useful separation can be accomplished by one alone.

Hence, it appears that strict logic cannot always be served if the aim is practicality. Furthermore, consideration will show that various points of view are possible, both in choosing what should go into the boxes, and in their arrangement. Sometimes a matter of definition is involved and frequently different names are used concurrently for fundamentally similar operations.

With these provisos, explanations and extenuations, therefore, it is safe to look at the result of one attempt to compromise between sheer logic and practicality. In the case of the handling of solids and semi-solids, four fundamental operations seem to be of greatest importance: the gathering of materials from freight cars, storage dumps and shipping containers; the storage of these materials; their inter-plant and inter-building transportation; and their conveying within the plant and through the process. None of these operations is mutually exclusive; all overlap. Their distinctions are founded primarily on types of equipment involved.

Fluids handling, the next box, may be subject to all sorts of points of view. This operation is beset with "heads," friction factors and viscosities; and yet when it comes to the actual movement of the fluids, apparently but three methods may be employed. Either gravity must do the work; or the fluid must be pushed; or it must be given a velocity which can be converted into pressure.

Numerous methods are possible in disintegration. Perhaps a logical classification would be based on whether a material is pounded, squeezed or sheared, but a more useful if less logical one is to effect a breakdown on the basis of purpose. Customarily, crushing, grinding and pulverizing are operations of increasing fineness, in the order given. Chipping and shedding are peculiar to fibrous materials. Masticating, as employed in rubber, combines an intensive shearing and mixing with a probable limited breakdown of the molecule. Spraying—disintegration for liquids—is again functional.

A functional approach also appears to be best suited for the mixing operations. Here the terms are quite confused. Mixing, sometimes called blending, is best kept to refer to solids and heavy slurries. Agitating is taken to include the handling of liquids and light slurries. Kneading refers to plastic masses, while emulsifying and dispersing cover colloidal mixings, the first with immiscible liquids, the latter, liquids and solids. The last term, diffusing, had best retain its most frequent meanings covering the natural migrations of gas molecules in gases and liquids in liquids.

Heat transfer presents a number of problems. As in fluids flow, there are so many considerations of conditions—resistances and potentials—that one is likely to forget that an operation is a means of accomplishing some desired end. Heat may be transferred by conduction, convection or radiation. But even more important, it may be made to flow either into the process, or out—hence, heating and cooling. Heat is supplied by chemical reaction, such as combustion, or by the ex-

penditure of electrical energy; but as every compressor operator knows, it also arises from mechanical work.

Cold produced chemically is of limited commercial interest and has been omitted, but the three great reservoirs of natural cold: air, water and ice, cannot be treated so cavalierly. Evaporative cooling covers numerous methods, but it has been thought best to lump them under two heads of spray cooling of water, and mechanical refrigeration in general.

Separation comprises by far the largest class of operations. If we examine the methods we find one group, the physical, where a definite energy change is involved. Practically all of these methods depend for their separation upon change of phase. In one group the wanted material is put into solution, in another, it is vaporized. Probably the only word of explanation needed with these physical separations is concerned with the solution group where several of the terms lack universally accepted meanings. By leaching is usually meant the solution of valuable material from gangue (with or without reaction); and by dissolving, the more or less complete solution of a solid or mixture of solids. Extracting most often means the solution of a solute contained in one solvent, by a second immiscible solvent. But it also means the solution of values by organic solvents.

A further glance at separation methods reveals a group where the electrical properties of the material undergoing separation are temporarily altered to effect its removal. The three sub-headings for this group are self evident. In what is clearly much the largest group of separations, no change in either energy content or electrical condition takes place and to this group has been given the name of mechanical.

All but one of the mechanical separations, interestingly enough, is caused by a resistance of some sort. In all sorts of filtration, in screening, sieving and bolting, in expressing by mechanical pressure, in dialyzing and in separation of gases by diffusion, the resistance is supplied by a membranous material, be it graded solids, cloth, screen, perforated metal, felt, parchment or porous plate. Removal of liquid or dust particles from gases, by impingement on solid surfaces, on wetted surfaces, or on liquid droplets, is comparable. Differential settling in all its forms depends upon the resistance of a fluid to the passage of solid particles which fall more or less rapidly as size or specific gravity varies. Only flotation is questionably placed in this group, for it may be argued that while the action of the floating agent is differential and selective, the separation thereafter becomes a matter of gravity segregation.

The last of this group, settling and decanting, appears to be mechanical separation and nothing else. Liquids, or liquids and solids of different specific gravities, are bound to stratify if left to themselves. Or by emphasizing the gravity differences in centrifuges, the operation may be hastened.

Both the control operations and those of the miscellaneous physical groups appear self-evident and require no discussion. Only the further fact needs to be recorded that as yet no means has been found whereby a logical classification of the unit processes can be added to the chart. This is a job that needs to be undertaken and it is to be hoped that some ingenious logician will find a way to scale the apparently impassable wall he will encounter.



# A Symposium of Unit Operations Appraisals

Much of the credit for the comparatively short time that has been required for chemical engineering to become a recognized profession is due to the early recognition of the unit character of chemical industry and to the realization that the same fundamental unit operations and unit chemical processes underlie the entire field. Additionally, this concept has made for continual technical progress by assisting in the study and improvement of one fundamental at a time. Consequently, it is worth while to assay the state of each of these units. In the articles appearing in the following pages, such an attempt has been made through a new device of technical balance sheets.

## HEAT TRANSFER

### CONVECTION Between Fluids and Solids

By **W. H. McADAMS**  
*Professor of Chemical Engineering  
Massachusetts Institute of Technology  
Cambridge, Mass.*

**R**EMARKABLE progress has been made in the last fifteen years in improving methods of predicting heat transfer by convection between fluids and solids. No small part of this advance is due to the simplification which results in studying separately the individual thermal resistances rather than attempting to correlate the more complex overall thermal resistance from the warmer to the colder fluid.<sup>1</sup>

The study of the individual resistances was accompanied by improvements in the technique of measuring surface temperatures, but even today the best technique is not always employed. A better knowledge of the mechanism has been obtained through study of relations between pressure drop and rate of flow of fluid, by measurement of velocity and temperature gradients across the

<sup>1</sup>Graphical methods are available for separating overall resistances into individual resistances, *Chem. & Met. Eng.*, 34, 599, (1927).

Heat transmission as a unit operation of chemical engineering may logically be divided into three main divisions: Conduction, Convection and Radiation. At the suggestion and with the co-operation of Prof. W. H. McAdams, the heat transfer balance sheet is so divided and its first two sections appear on the following pages. Radiation will be published in our June issue.—EDITOR.

fluid stream, and by the use of color bands to indicate the nature of fluid motion past the surface. Attempts to predict rates of heat transmission by applying the conduction equation to moving fluids have met with little success, due to difficulties too numerous to mention here. Nevertheless, such methods have indicated valuable schemes of correlation, and there is reason to believe that they may lead to simple syntheses of overall relations in complex cases. Dimensional analysis, although often misused, proves a useful tool in planning experiments and in interpreting results. In the last decade more and more workers have come into the field and have furnished data of considerable value. Consequently, recommended general relations are now available for a number of important cases; the percentage deviation which may occur naturally depends upon the quality and extent of data underlying each particular correlation. For some years the lack of agreement between expected results and actual performance has not been so large as some skeptics suspected nor as small as some enthusiasts claimed.

There is given in Table I a com-

parison of "Assets and Liabilities" for cases which arise frequently. With regard to the need of performance data on commercial heat transfer equipment, it is hoped that manufacturers in chemical and allied lines will permit publication of such data.

### THERMAL CONDUCTIVITY

By **GORDON B. WILKES**  
*Professor of Industrial Physics  
Massachusetts Institute of Technology  
Cambridge, Mass.*

**I**N THE past ten years much has been accomplished in regard to standardization of test methods, and many of the errors of early investigators have been recognized and eliminated. During this period many new insulators have been developed so that we now have insulating materials that cover a range of temperatures from the lowest to as high as 2,700 deg. F. The mathematical theory is apparently in satisfactory condition, but in many cases data are insufficient to permit exact application of the theory. Furthermore, the mechanism of conduction in many cases is little understood, thus handicapping development of better insulators.

In most cases of intermittent heat

**Table I. Balance Sheet for  
HEAT TRANSFER BY CONVECTION**

**ASSETS**

**LIABILITIES**

**General Principles<sup>1</sup>**

In general, given desired heat load and available terminal temperature differences, required heat transfer surface can be computed with reasonable accuracy.

Data are lacking for some cases, as noted below. When dealing with decomposable materials in general, insufficient data are available to determine maximum permissible temperature difference.

**Mean Temperature Difference**

Principles well understood, and rules for computing proper average from terminal values are available for important cases, including counter flow, cross flow, and flow through baffled exchangers.

Integration is still necessary for unusually complicated cases.

**Turbulent Flow of Gases Inside Tubes**

Concordant data for several gases are available to support a general correlation.

Exact effect of high gas temperatures is in dispute. Too few measurements for pressures above twenty atmospheres. Dust and other deposits retard heat transfer.

**Turbulent Flow of Liquids Inside Tubes**

Data for a number of fluids support general correlations.

For liquids having high viscosity at room temperatures, the effect of substantial temperature gradients along tube is not adequately investigated.

**Streamline Flow Inside Tubes**

General method of attack is available.

Insufficient data available to establish general relation for extrapolation.

**Fluids Flowing at Right Angles to Tube Banks**

Available data support general relation for flow across staggered tubes, without baffles.

Measurements covering a wide range of Reynolds numbers are needed for flow through variously baffled exchangers.

**Condensation of Steam**

Recent work indicates substantial differences in results with dropwise and film-type condensation. Rough estimates are available for film-type condensation. In a number of cases the steam-side resistance is not of first importance. Effect of superheat is fairly well understood. Effect of non-condensable gas can be estimated roughly.

More data are needed for dropwise condensation and factors influencing it. Few data are available for large multi-tubular condensers. Further data are needed on effects of steam velocity and arrangement of baffles. Additional data regarding effect of non-condensable gases are desirable.

**Condensation of Single Vapors Other Than Steam**

For a single horizontal tube the data are in rough agreement with an equation for streamline flow of condensate. Data for vertical tubes indicate possible effect of change in shape of curve near critical Reynolds number.

Data are needed for horizontal multi-tubular condensers. More data are needed for vertical tubes of various heights. The effect of non-condensable gas should be further investigated.

**Condensation of Mixed Vapors**

Rough methods are available for estimating condensation of mixtures of steam and organic vapors.

Further data are needed on the effects of non-condensable gas and vapor velocity.

**Boiling Liquids**

Some information is available as to relative resistances encountered when a given temperature difference is employed in boiling a number of different liquids. When boiling a given liquid rough relations are available as to effect of increasing temperature difference. It is realized that surface conditions may play prominent roles.

More information of this sort is needed, particularly in evaporators of commercial size. Liquor level seems to be a factor of importance in commercial evaporators. Much more work is needed to evaluate effects of surface conditions.

(Continued on page 234)

Table I (Convection) Continued

Natural Convection

The nature and quantitative effect of many important factors are well understood for certain arrangements of heating surface.

In some cases the magnitude of the free convection resistance is not of first importance.

Additional data for full scale operation are needed relative to common arrangements of heating surface, such as heating coils immersed in liquids, liquids or pastes in jacketed vessels with and without agitation.

It is difficult to predict in advance the rate of deposition of scale or reaction products on heating surface. The solidification of part of the charge should not be overlooked.

Finned Heating Surface

Theoretical relations are available for temperature gradients in finned surfaces. Considerable data are available on heat transfer from finned surfaces to gases.

More data seem desirable regarding the effect of dimensions and arrangements of fins for flow of gases over a wide range of velocities together with pressure drop characteristics.

<sup>1</sup>Unless changes in state are specifically mentioned, the discussion pertains only to warming or cooling.

operations, it is often forgotten that the total heat capacity of the insulator is frequently of major importance as regards the savings of fuel and time. The recent development of very light weight insulation utilizes the low conductivity of air by minimizing convec-

tion, and nearly eliminates radiation by choice of surfaces of low emissivity; thus producing a good insulator with small heat capacity, due to its extremely light weight.

Although industrial management has long recognized the economy and utility

of insulation, it is only during the last few years that the general public has been acquainted with the advantages of insulation, especially for homes. The balance sheet for thermal conductivity is presented in Table II which appears below.

Table II. Balance Sheet for THERMAL CONDUCTIVITY

ASSETS

LIABILITIES

Gases

Theory apparently ahead of experimental work. Values on air fairly satisfactory.

No standardization of method. Precise data needed for wider range of temperature and at extreme high and low pressures. Data on mixtures are inadequate.

Liquids

Value for water fairly satisfactory.

No standardization of method. Data needed for more materials. Not much precision in many cases. Temperature coefficient of conductivity needed.

Solids

Insulators Below 200 deg. F.

Well standardized and values well known.\*

Variation with moisture content and porosity needed.

Insulators Between 200 and 1000 deg. F.

Well standardized and values fairly well known.\*

Temperature coefficient and effect of porosity needed.

Refractories Above 1000 deg. F.

Testing apparatus available.

No standardization of method. Temperature coefficient needed. Values vary considerably.

Building Materials

Well standardized and values fairly well known.

Metals

Pure common metals fairly well known at moderate temperatures.

No standardization of method. Wider temperature range and temperature coefficient needed. More work on alloys and impure metals.

Crystals

Some data up to 212 deg. F.

Practically no data above 212 deg. F. Important for theory.

\*Standard methods of test may be found in Reports of the Heat Transmission Committee, Division of Engineering and Industrial Research, National Research Council, 40 West 40th Street, New York City.



# FLOW OF FLUIDS

By **RAYMOND P. GENEREUX**

*Chemical Engineer  
E. I. du Pont de Nemours & Co.  
Wilmington, Del.*

**C**ONSIDERABLE advancement toward a more complete understanding of the principles of fluid flow is evidenced by the number of adequate papers and books published in the past few years. The greatest stride has been the gradual adoption of rational and fundamental rather than empirical formulas. Formulas involving coefficients dependent upon dimensionless groups such as Reynolds number have been "rediscovered" by many who formerly

used empirical formulas applicable only to narrow ranges of the variables involved. For example, the Fanning or Darcy equation for flow in pipes, which involves a friction factor dependent upon Reynolds number and relative roughness, has been proved applicable to all sizes, shapes and kinds of pipe and to any velocity and fluid. Correlations of a multitude of data have resulted in friction factor curves which

---

---

## Balance Sheet for FLOW OF FLUIDS

### ASSETS

Principles of statics are well-known.  
Methods for determining viscosity are well standardized.

Some viscosity data have been collected and converted to a common unit, the centipoise.

Fairly complete roughness factors have been correlated.

Correlations of data on flow through tube banks, tower packings, catalyst beds, etc., have produced more rational design formulas.

Rational formulas, based on coefficients well substantiated by experiment, are available for calculating flow of any fluid in open and closed conduits.

Factors for pressure drop in fittings have been tabulated in form of number of diameters of straight pipe equivalent to fitting.

Piping can be designed on economic basis by balancing pipe and pumping costs. Welding fittings are available for reducing pressure drop and leaks.

Recent correlations of heat-transfer and fluid-flow data make possible more intelligent design of plant equipment.

Some knowledge of fundamentals of gas-gas, liquid-liquid, and liquid-solid mixing has resulted from investigations recently reported in literature.

Fans, blowers and compressors are available in kind and size generally commensurate with need.

Meters for flow in pipes and channels are obtainable in kind, size and accuracy suitable to need. Coefficients are available for wide ranges of meter size and Reynolds number.

Gages and manometers of adequate accuracy are generally available.

### LIABILITIES

Continued improvement in methods of teaching principles of fluid flow on basis of dynamic similarity is imperative if advances so far made are to be generally assimilated and subject is to be carried toward perfection.

Viscosity data are in general scattered and expressed in various units, and are entirely lacking for many pure fluids, mixtures, suspensions, slimes, pseudo-plastics and thixotropic substances.

Very little is known of the flow of liquids containing solid particles in suspension.

Data on pressure drop are needed for rational design of baffled heat exchangers.

Additional data on pressure drop in packed towers are needed to establish means for evaluating various packings.

Little is known of the effect of gas and liquid rates on pressure drop in absorption towers, of flooding or loading rates, or of effect of surface tension.

Further application of streamlining would be effective in reducing pressure drop in fittings and valves.

Study is needed to effect improvement on flow of fluids at inlet and outlet of reaction equipment in order to obtain optimum fluid distribution.

Information on mixing fluids is generally empirical and data on equipment are not generally available; considerable study of fluid mixing is needed to raise this unit operation to status of measurable efficiency and rational design.

Fan, blower and compressor design would benefit by further application of more advanced state of aero- and hydrodynamics.

Circulation of molten metals by thermal diffusion should be stressed as more generally suitable than mechanical means.

substantiate the method used, i.e., dynamic similarity. The principles of hydro- and aerodynamics are thus used to best advantage for design purposes.

The principles of dynamic similarity have been used with considerable success in determining rational formulas (or coefficients) for such conditions as flow through orifices and nozzles, across banks of tubes, through beds of packed solids, past obstacles, and the motion of objects through fluid media. It is thus possible for the data of various investigators to be compared readily, the range of the variables to be extended, the gaps to be filled, and unnecessary duplication to be avoided.

Viscosity data are necessary in calculations of Reynolds number. Further correlations are needed to clarify the state of the data and to suggest fields for investigation. The greatest lack is in data on gas, gas-liquid, liquid, and liquid-solid mixtures; examples of the latter classification are slimes, slurries, pseudo-plastic and thixotropic materials.

Devices with accuracy commensurate with requirements are available for measurement of flow. Large savings result from wise selection of the device most suitable to the job.

Pipe lines can be designed economically by balancing costs of pipe and pressure drop. Fairly complete information is available on pressure drop in fittings and valves, but considerable improvement in their design is possible by applying aerodynamic knowledge.

Although data on pressure drop due to flow across tube banks and through beds of solids have been correlated and rational formulas obtained, many types of baffled exchangers and packings have not been investigated on this basis due to the lack of data. Flooding rates and the effect of wetting in packed towers have had little attention, although some information is available on the film thickness and liquid velocity in falling film towers. Data are needed on the gas and liquid capacities of falling film towers.

Improvement in design of fans, blowers, compressors and pumps is certain if kept in step with advances in aero- and hydrodynamics.

It is hoped that the recent papers on mixing will give impetus to further study of this unit operation. Some information is available on gas mixing, but knowledge of liquid mixing is at present almost entirely empirical.

Study of inlet and outlet conditions and the distribution of fluids within equipment, such as exchangers and reaction vessels, is necessary to obtain maximum utilization of surface and space.

Recent correlation of heat transfer and fluid flow data has made available rational means for economic design of heaters and coolers.

# SAMPLING

By J. W. STILLMAN

E. I. du Pont de Nemours & Co.  
Wilmington, Del.

**S**AMPLING has been defined (Baillie, *Chem. Trade J.*, Vol. 66, 1920, p. 333) as "that process whereby a representative and comparatively small portion of material is selected from a large bulk and preserved under such conditions as shall prevent contamination or avoidable alteration, with a view to the formation of valid conclusions regarding the suitability of the bulk for specified purposes." This comprehensive definition makes the sampler responsible for getting a representative portion from the bulk and having it in the same condition at the time of the analysis or test. This duty is not generally realized and is often overlooked. Another fact which needs to be emphasized in connection with this problem is that the character of the bulk changes on storage or transportation, through surface weathering, or due to segregation of different sizes.

Since practically always the sampler has to deal with non-homogeneous ma-

terials, the procedures for sampling are in constant need of refinement to make the small portion resemble the average character of the bulk more closely. This is regularly being done by the A.S.T.M. and other cooperating agencies and in their specifications definite directions are given for the sampling of the material in question. In agreements between buyer and seller, the method by which the samples are to be taken should be mentioned in order that a fair test can be made as to whether the terms of the agreement are being fulfilled.

It would probably be well worth while if, in connection with courses on quantitative analysis, the colleges and technical schools would direct more attention to the problems of sampling, both from a theoretical standpoint and from the point of view of practical sampling of typical materials. This would provide the student with the necessary background to see the close relationship existing between sample and analysis.

## Balance Sheet for SAMPLING

### ASSETS

Principles underlying the taking of a representative sample are simple: an exercise in applied mathematics.

Rules for sampling of different types of materials have been worked out.

Proper sampling in conjunction with chemical and physical analyses makes possible rapid evaluation of materials in large bulk.

Proper sampling of products in conjunction with analyses gives the engineer data for judging efficiency of his process.

Researches on methods of sampling, particularly in the metallurgical field, have been extensive and have resulted in helpful refinements.

A number of implements are on the market for use in practical sampling.

Automatic sampling devices can be used when materials (solid, liquid, gas) are being conveyed continuously from one point to another.

### LIABILITIES

Information on procedures for sampling various materials is not emphasized in training of engineers.

Materials in general are not homogeneous and, therefore, best methods of sampling are approximations.

Improper sampling makes results of later analyses or tests of no value, and may cause serious errors.

The element of personal judgment carries great influence in the practice of sampling.

In general, sampling is a more complex process than is usually realized.

Surface samples from piles, etc., are unreliable due to segregation.

Surface samples from shipments loaded in layers, may not be representative of lower layers.

# MIXING and AGITATION

By KENNETH S. VALENTINE AND GORDON MAC LEAN

Respectively, Sales Manager and Sales Engineer,  
The Turbo-Mixer Corporation,  
New York, N. Y.

IN THE PROFIT and loss statement presented we are able to report a favorable balance. However, lest we be thought complacent, there are still many ways in which the picture must be improved before a really satisfactory condition will exist.

A move in the right direction in connection with the mechanics of mixing is the work of Hixson and Crowell (*Ind. Eng. Chem.*, Vol. 23, pp. 923, 1002, 1160, 1931), and Hixson and Wilkens (*Ind. Eng. Chem.* Vol. 25, p. 1196, 1933). This study of the efficiency of mixing through rates of dissolution is the only fundamental investigation of mixing efficiency which seems to have evolved any worth-while formula. It has, however, yet limited practical value because it has been applied to too few types of materials and of mixers.

More fundamental laws than this should be evolved. Knowledge is necessary, for instance, regarding the exact method by which the momentum imparted by a mixing element to a body of liquid within a container is utilized—how and where it is dissipated as heat.

From a more practical point of view, data are needed on the performance (power required, speed of mixing, dispersive ability) of all types of mixing elements in all consistencies of any combination of liquids, solids, and gases. A beginning along this line was made by Badger, Wood, and Whittemore (*Chem. & Met.*, Vol. 27, p. 1176, 1932), but it involved only the easiest material to handle, dilute aqueous solution, and elementary types of paddles.

An extensive study of consistency is also required, not only the consistency of stationary and nearly stationary masses, but also the consistency of moving masses subject to shear within a container. The work of R. V. Williamson (*Ind. Eng. Chem.*, Vol. 21, p. 1108, 1929) and Williamson and Heckert on this subject is significant.

A standard means or machine for measuring consistency should be developed and agreed upon—one for gases, one for liquids and liquid-solids mixtures, one for heavy pastes and plastics, and one for solids. As an example of what can be done along this line, see the original data on "Apparent Viscosity" and the modified Stormer Viscometer, published for the first time

in the "Chemical Engineers' Handbook," pp. 1271-75.

There is a definite lack of standards. It will literally be found that hundreds of different shapes or sizes of mixing elements are being used today to do exactly the same work on exactly the same quantity of the same material. This condition results from our lack of fundamental data. Until it is shown and published exactly what each form, width, curvature, and type will do, every manufacturer of mixers, and even the user of

mixers will follow the dictates of his own experience.

Better design of containers (tanks and vats) would aid in solving mixing problems. Conditions of best flow should be favored, also pockets and crevices of all sorts should be avoided.

Less expensive designs of equipment for mixing corrosive materials should be evolved. Progress has already been made along this line. This applies not only to the design of the major parts of mixers, but also to valves, bearings,

---

---

## Balance Sheet for MIXING

### ASSETS

Progress in the formulation of laws governing mixing.

Small equipment for laboratory and pilot plant is now available.

Improved technique in translating laboratory results to plant scale.

Manufacturers' laboratories now also offer preliminary tests on actual material to be handled.

New types efficiently cover broader range of consistency.

Improved types constantly developed.

Power and time savings.

Better dispersions produced.

Higher rate of heat transfer.

High viscosity mixing and dissolving.

Gas-liquid reactions.

Larger mixers being evolved with no loss of efficiency or yields and with savings in first cost and control testing.

Improved technique in translating batch results to the basis of continuous flow.

Better drives being evolved.

Progress in the building of special metal mixers.

### LIABILITIES

Mixing still too much an art and not enough a science. Fundamental laws governing mixing should be evolved.

Chemical engineering research on mixer types and consistencies greatly needed.

Lack of standard method of describing consistency accurately. Too much thought of specific compounds and not enough of the common properties of different compounds.

Lack of standards. Use of different types of mixers in the same and in different industries for essentially the same problem.

No efficient universal mixer for all consistencies.

Time of mixing often the bottle neck in an industrial process. Increased speeds of mixing also would decrease mixing plant investment.

Lack of flexibility with respect to quantities to be mixed.

The attitude of some users, "what we have is good enough," and widespread use of inefficient homemade mixers.

Lack of appreciating that the container is an integral part of the design.

Less expensive, yet efficient mixers for extremely corrosive mixtures.



stuffing boxes, and other parts. Valve manufacturers should note that a really good flush valve is needed. There is none on the general market at present.

The operating end also suffers from a lack of mixer standards. In many cases, an entire industry has gone to the unnecessary trouble of developing a special mixer, when a simpler machine, doing the same thing on a material of the same characteristics, but with a different name, was already available in another industry. On the other hand, hidebound tradition may cause one industry to continue using the same old inefficient type long after the mixer ideal for the purpose has been developed in another industry.

The time may not be so far distant when a mail order for mixers to handle a liquid of 520 poises pure viscosity, plasticity of A73n4 falling to R22ml (or what have you) at the finish, 20 per cent plus by weight of 40 mesh

solids of 1.4 sp. gr., object—dissolving of the solids—can be filled with the assurance that the type supplied will exactly fulfill the requirements. The last few years have seen a great improvement in the comprehension of what types of mixers are best suited to different problems, but even today consistency is all too often described as "pasty," "like molasses," or "mushy," when actually in each case there may be a combination of viscosity, plasticity, or even inverted plasticity.

This makes the manufacturer's laboratory still the proving ground and it takes a highly developed business acumen, all too rare, for the manufacturer of one type of equipment to reply to an inquiry with the information that a competing mixer will do a specific job better. Consistency is the chief guide in choosing the proper equipment and deserves much more attention than it is receiving.

fore a full range of controlling devices is available.

At the present time much of the equipment used for moving materials was developed for use in industries other than chemical manufacture. While it serves well the needs of the chemical engineer, it is often designed to operate at rates that do not correspond to the best speeds of the processing equipment. Development of a line of equipment with speeds of operation synchronized to chemical plant operation is indicated.

Equipment for handling gas and liquids is probably as flexible as can be reasonably expected. Conveyors and overhead handling equipment for solids are, however, not flexible as at present designed unless the portable type is used. Portable equipment now available is limited in types and capacities. There is need for the design of equipment of sufficient flexibility to permit changes in chemical manufacturing operations without the necessity for installing much new equipment when changes are made.

A special case of the need for flexibility occurs in cases in which new or additional products are to be made. Much materials handling equipment is so designed that, once installed, it is accommodated only with difficulty to handling other products than those contemplated in the original plant layout. Often this difficulty does not arise if sufficient foresight was employed in making the original plant design.

Generally speaking, it is desirable that chemical engineers develop equipment for the movement of materials designed specifically to give good service in the chemical engineering industries, in place of depending to the extent they now do upon equipment originally designed for other purposes.

## MATERIALS HANDLING

By G. L. MONTGOMERY

*Mechanical Engineer  
New York, N. Y.*

**E**QUIPMENT for the movement of materials has, broadly speaking, been developed to a point where it can meet the needs of the chemical engineer. Whether the material to be handled is a solid, a liquid, a gas, or a container, efficient and economical devices have been designed which are sufficiently flexible to fit into any of the manufacturing processes ordinarily used.

On its face, this would seem to be an unusually fortunate situation. There are, however, certain considerations concerning materials handling equipment that the chemical engineer must keep well in mind in planning for the use of this equipment.

The first qualification concerning the statement made in the opening paragraph is that it applies only to the general line of problems involving the moving of materials. Where a chemical hazard, either to the equipment or the operating personnel, is involved, equipment that is suitable for general uses may be found inadequate. Special equipment for such purposes has been designed, but it is always much higher in first cost and often less efficient in operation. Conveyors to resist chemical attack or avoid explosion hazards, pumps of special design for handling corrosive chemicals, and similar devices are procurable, but development is needed to bring down the cost and improve the efficiency of these devices.

In the operation of equipment for the movement of materials, three lines of needed improvement must be considered. Much progress has been made in recent years in the development of automatic controls for conveyors, pumps, compressors, and similar machinery. There still remains, however, much to be done be-

### Balance Sheet for MATERIALS HANDLING

#### ASSETS

Equipment available for efficient and economical handling of all ordinary products—solids, liquids, gases and containers.

Special equipment available for meeting some of the problems that arise in handling corrosive or hazardous chemicals.

Controls governing loading, unloading, speed and other factors have been developed for some types of materials handling equipment.

#### LIABILITIES

Solids conveying equipment, except portable types, lacks flexibility for accommodation to factory changes or new products.

Speeds of available equipment not always suitable for chemical plant operations.

Much special equipment now available is relatively high in first cost and inefficient in operation.

Special equipment for all chemical plant operations not yet available.

Controls specifically designed for chemical plant operation are not available in many cases.

By LINCOLN T. WORK

Assistant Professor of Chemical Engineering  
Columbia University, New York, N. Y.

# DISINTEGRATION

## Balance Sheet for DISINTEGRATION

### ASSETS

Analysis of manner of loading and fracture characteristics of materials under stress creating clear concept of mechanism of disintegration.

Experimental determination of energy requirements permits estimation of cost of power when fineness is varied.

Studies in grindability yielding quantitative values for materials and enabling computation of mill capacity and power from laboratory tests.

Mill designs have been improved, and new designs created.

New disintegration methods in process of development, as steam or air-jet impact, thermal-expansion, and flash-vaporization types.

Closed circuit operation decreasing power and maintenance costs and yielding closer size control; warm air for separators permits use of wet feed, with drying in mill.

Mill construction improved by use of wear-resistant alloy parts or by rubber lining; insulation used to diminish sound.

### LIABILITIES

Relation of types of disintegrating processes to this mechanism is controversial; problem of mechanism is complex and not quantitatively defined.

Much energy not used for disintegration is unaccounted for.

Data on grindability incomplete; fineness distribution not revealed by grindability data; correlation of grindability data with mill performance uncertain when feed is moist or mill clogged.

Developments in disintegration impeded through limited cooperation of mill users.

Particle size distribution of disintegrated materials limited by inability to prevent formation of fines when coarse sizes are desired, and to reduce to micron sizes.

Separators operate with limited effectiveness due to design and to high concentrations of solids required for economic operation.

Maintenance costs are still uncertain; require correlation with grindability and operating conditions.

**D**ISINTEGRATION processes in the chemical industry have been developed and extended largely on a practical basis. The theoretical background which is essential to create major trends has been scant. This was due to the complex and diverse nature of the problem and to lack of suitable tools of measurement. Major developments in the field have been made by mill producers. Their progress was necessarily slow because economic justification is limited to the volume of sales. Of late some of the users of disintegrating devices have come to a realization that their investment in such equipment is large and that there are opportunities to effect economies of operation of considerable magnitude. In this field particularly it is apropos that a balance be established and the trend of further development visualized.

For years disintegration processes were studied from the viewpoint of theoretical energy and there was a great dispute on the theories advanced by Kick and Rittinger. It is recognized that the theoretical energy of grinding which they considered is but a small part of the total, and therefore that the total energy required for disintegration cannot be deduced from theoretical analysis. Experimental work has shown that the theoretical energy needed to cause disintegration is in the range of a fraction of one per cent up to 25 per cent of the input to the mill. However, experimental work using reasonably accurate methods of fineness measurement has shown a relation between overall grinding energy and the new surface developed. For the present this relation is limited to certain pulverizers, notably the ball mill, but the study should be extended to other types using different kinds of crushing action.

It has been known for sometime that materials differ in the manner in which they disintegrate. For example homogeneous materials with a limited tendency to cleavage show a characteristic type of size distribution after grinding. Even within this class of material the relative amounts of coarse and fine particles differ for individual materials. When a substance is not homogeneous

its normal fineness curve may be affected by tendencies for cleavage as with mica, or by cellular or fibrous structure as with wood or asbestos.

Within recent years grindability studies have been made in order to evaluate quantitatively the ease with which materials can be disintegrated. The present procedure consists in grinding a dry sized powder in a standard mill for a stated period of time and then noting the change in fineness. The new surface developed is the criterion of grindability, but the fineness characteristics are untouched in these investigations. Grindability studies were first made with coal and have been

carried to other materials so that now there are several hundred figures assigned to stated materials, which figures serve as an indication of the energy needed to create a unit of new surface. With such measurements determined in the laboratory, the power and capacity requirements may be predicted when the material is used in a given type of mill. There is still need for more data on grindability.

Disintegration processes are limited with respect to the size distribution which can be obtained. A given material when first broken will create impalpable powder, and while the amount can be reduced by the selection and

operation of the mill, some powder is inherently formed in the nature of the breaking action. There is a normal distribution of sizes occurring during grinding operations which makes it impossible with the present methods of disintegration to secure all of the materials in a uniformly coarse size. Furthermore there is a limit in the size reduction which may be obtained. Costs go up rapidly when processing materials so that all particles are under 5 or 10 microns. Even at high cost it appears impossible to apply grinding forces effectively on such fine sizes of materials, and it is an exceedingly slow operation to reduce oversize in this range. Classification schemes are used to yield fine products, but when the cut is made at very small sizes these do not generally operate efficiently. The problem of size distribution with respect to material, mill type, and classifier performance has been complicated by the difficulty of measurement and little is known of those relations. Exact methods of measurement have been perfected, but they are cumbersome and expensive. There are several rapid methods most of which give a single constant as indication of size, but a few methods, chiefly of the sedimentation type, give distribution curves. With the aid of the more rapid methods of size measurement, there should be significant developments of both a theoretical and a practical nature.

Disintegrating mills are of many different designs and they vary in the manner in which they apply stress to the material. For example, roller mills exert a direct pressure upon a mass of material; impact mills exert a rapidly applied force which varies with the mass of the particle; and with both Chilean and colloid mills an action of shear is exerted. Consequently, certain materials are quite frequently associated with certain mill types. These differences in mill characteristics have been noted empirically, and the field of use of any mill defined by experiment. There have been few changes in the coarse crushing equipment, and most of the alterations in design have had to do with mills operating in the fine size range. The Fuller ball ring mill has been extensively modified into the new Babcock and Wilcox mill. The ring and roller types of mills have been modified in the interest of simplification in construction and ease of replacement of parts. The Bethlehem pulverizer stressed this particular feature. Quiet operation of the mills has been gained by use of insulation.

Maintenance is one of the important elements of the cost in mill operation. Stresses from impact and the abrasion are the chief factors involved. With grindability data on materials, and with hardness tests on wearing parts it may

be possible to establish a more quantitative basis for the estimation of this factor. Abrasion loss is being steadily reduced by the use of alloys and successful results are reported with the use of soft rubber linings in ball mills.

In still finer sizes there have been marked developments in the colloid mill. More careful control of clearances, the use of lower speeds, the use of cooling devices, and the use of pressure feed have expanded its scope and improved its performance.

Probably the most outstanding trend in disintegrating processes lies along the lines of alternatives to grinding mills. Heating of rocks to high temperatures and quickly quenching is one method. This obviously depends on using the coefficient of thermal expansion over a

sharp temperature gradient to produce the stresses which cause rupture. Due to the fact that these stresses operate largely to produce intermediate rather than fine sizes it may be possible to produce more uniformly sized materials. Another method is to place the material in superheated water, and when the interstices are filled, to release the pressure. The bursting force of the steam created within the particle causes rupture. This type of method is actually used on a production scale in the disintegration of wood fiber. The use of jet-impact devices also offers promise in this field. Finally, chemical disintegration methods as solution and subsequent precipitation represent another alternative which is finding specific application in several places.

## SCREENING

By LINCOLN T. WORK

*Columbia University  
New York, N. Y.*

**S**EPARATING devices covered under this head represent wire mesh, perforated plate, and slots. Standard screen scales have been devised and adhered to by manufacturers; and perforated plate, largely in the sizes above one-quarter inch diameter have also been standardized as to dimension and spacing of apertures. In both these, ruggedness and maximum of available area for apertures have been balanced.

There is confusion in several industries where both wire mesh and perforated plate are used. Some attempts have been made to correlate results from these two separating devices on the basis that the diameter of a round hole bears a certain relation to the diagonal of a square aperture. It has not been possible to correlate these results rigidly

because of particle shape. A round particle passing through a given plate opening would pass a wire mesh of similar aperture, while a flat particle passing the same round opening would pass on the diagonal of a wire mesh of smaller aperture.

Some efforts have been made to evaluate the capacity and efficiency of screens, but the data are inadequate for generalization in design. The complexities of size distribution have prevented the attainment of a simple basis of estimating efficiency. Many types of vibrating devices have been used to increase both capacity and efficiency. The "blinding" of screens due to the binding of particles in apertures has been a serious problem especially in commercial application of finer mesh. A self cleaning grizzly has been developed in connection with this difficulty. However, the problem is not so simple with wire mesh. The method of vibration and the use of balls or other subjects have represented efforts to reduce the magnitude of the effect.

### Balance Sheet for SCREENING

#### ASSETS

Specifications and manufacture of wire mesh and perforated plate well standardized.

Agitating devices and screen-cleaning methods developed which improve screen capacity and efficiency and tend to prevent "blinding."

#### LIABILITIES

Correlation between wire screen, perforated plate, and slot apertures cannot be rigidly developed as the shapes of particles alter results.

Present data on capacity and efficiency inadequate for broad generalization; "blinding" serious problem in finer meshes.



By H. C. DUUS

E. I. duPont de Nemours & Co.  
Wilmington, Del.

# REFRIGERATION

**M**ECHANICAL refrigeration is a process for extracting heat from an environment at a low temperature and passing it on to an environment at a higher temperature through a working medium. The process most commonly employed for this purpose is the exact reverse of the process employed in the steam engine, and thanks largely to the science of steam engineering, refrigeration was put on a firm theoretical basis very early in its development. The fundamental thermodynamic properties of a large number of possible working media have been determined, and their suitability for any given set of conditions can rapidly be determined.

With regard to the properties indicating the rate at which the heat can be extracted, the data are far less satisfactory. No extensive heat transfer measurements have been made on any refrigerants other than ammonia, but it is known that the rates are quite different for various materials (McAdams, "Heat Transmission," p. 288). In ordinary practice, a slightly underestimated coefficient of heat transfer can be compensated by increasing the temperature gradient, but in refrigeration this is to be avoided for the reason that the power requirements are directly proportional to the difference in the operating temperature of the cooling coils and the condenser. In most installations this temperature difference is not above 100 deg. F. and usually much less. Every degree added to the gradient, therefore, increases the power costs by one per cent or more.

A very important asset of refrigeration is the large number of refrigerants now available commercially to satisfy any particular requirement. Ammonia is the one used in largest amounts where cheapness and maximum efficiency are required. For uses requiring safety in case of leakage, carbon dioxide is a good substitute, and where the pressures of carbon dioxide are inconveniently high, difluor-dichloromethane (Freon) may be used. If the reactivity of ammonia with certain chemicals, such as chlorine or acids, is objectionable, propane can be charged into the refrigeration units without materially altering the performance. Where low-pressure refrigerants are required

to minimize leakage, various materials boiling around room temperature are satisfactory. For centrifugal compressors which require low pressures with high gas density, various halogenated compounds of high molecular weight have been used. If any other requirements are set up, the ingenuity of the chemist would probably not be greatly overtaxed to supply a satisfactory material.

All refrigerants, however, cost money, a marked liability when one considers the cheapness of water, the working medium of the steam engineer. Water could be, and is, used as a refrigerant but for cooling below its own freezing

point, it is clearly unsatisfactory. In the vapor compression cycle it is also somewhat less efficient than most refrigerants. Another possibility is air which is also used, but is unsatisfactory because of its practical inefficiency. Its theoretical efficiency is the highest of all refrigerants since it operates on the reversed Carnot cycle, but, owing to insufficient heat transfer, the units must be inordinately large to provide reasonable capacity. Air was proposed as a working medium for heat engines by Ericsson, but failed to develop for the reason just indicated. If the heat-transfer rate from air to metal wall could be made as great as from a boil-

## Balance Sheet for REFRIGERATION

### ASSETS

Fundamental thermodynamic principles well understood.

Wide variety of refrigerants available for most diverse requirements.

Thermodynamic properties of many refrigerants have been determined.

Air and water are perfectly safe refrigerants.

Vapor compression machines have reached a high state of development.

Small automatic absorption units now available.

Steam jets, combining prime mover and compressor in one unit, have been greatly developed in the last few years.

Distribution of cold by means of brine now well worked out.

Distribution by direct circulation of refrigerant much more efficient.

### LIABILITIES

Adequate heat transfer data lacking for most refrigerants except ammonia.

No refrigerants available which are as cheap as water or air. Neither of these are wholly satisfactory, former because of high freezing point, latter because of low heat transfer rate.

All refrigerants manifest some chemical or biological activity.

Large-scale absorption machines are gradually becoming obsolete.

Large automatic absorption machines are too costly to build.

Steam jets limited in their application to conditions where water is suitable as a refrigerant.

Dissipation of extracted heat may put too heavy a load on municipal water supplies.

Dissipation to the atmosphere cuts down rate of heat transfer.

Distribution of cold by brines results in one extra heat transfer.

Distribution by direct circulation of refrigerant somewhat hazardous in case of leakage.

ing liquid, air would probably be a much more popular refrigerant.

Most refrigeration is done by vapor compression machines which involves the use of power. Power can be dispensed with in an absorption machine, where heat is used to produce cold. Excellent small units without moving parts and automatic in operation are now available, but they are too costly as yet for industrial work. The old type of absorption machine, requiring very careful manual control, is gradually becoming obsolete. Another development for the utilization of heat in refrigeration which combines the prime mover and the compressor in one unit is the steam jet. These are being made now with high mechanical efficiency,

much improved over the poor efficiency which was a serious objection to their use a few years ago. They will probably be limited in their application to temperatures above the freezing point of water, but there is still a wide field.

A problem of some concern if refrigeration becomes more general is the disposal of the heat extracted at low temperature. This goes into the cooling water of the condenser, but with the increasing demands on municipal water supplies, cooling water may not be so readily available. The atmosphere furnishes a sink of unlimited capacity for such heat, but here again inadequate heat transfer coefficients set up a serious obstacle.

The distribution of refrigeration is

to some extent inefficient where brine systems are in use. Brines are corrosive, and require considerable power for circulation. The most serious objection, however, is that an extra heat transfer must be made, which could be avoided if the liquid refrigerant could be circulated directly. Moreover, the refrigerant would be distributed at the condenser temperature, whereas brines, which must be circulated cold, pick up some heat in transit. Owing to the general chemical and biological activity of refrigerants in case of leakage, direct distribution of cold in this manner is commonly avoided. With the developments in steam jets, the possibility of cooling brines directly by evaporation suggests a compromise of some promise.

## LEACHING, DISSOLVING, EXTRACTING, AND PERCOLATING

By E. J. ROBERTS

*The Dorr Co., New York, N. Y.*

IN THE ORDINARY use of the word, leaching is one of the broadest of terms. It is used to denote the dissolving of some component of a solid phase or phases whether by simple solution in water or by chemical reaction of a reagent dissolved in water with or without the production of another solid phase.

The variables affecting the rate and completeness of solution are so many and diverse that most problems are solved by rule of thumb and by small scale tests on the particular solid involved. Very extensive testing programs are sometimes necessary in order to determine the conditions leading to the most economic operation, maximum recovery, maximum strength of solution, etc. In some cases agitation appears to be the principal factor aside from temperature and surface area, as it is in the case of ordinary dissolving. Hixson and Wilkens (*Ind. Eng. Chem.*, Vol. 25, 1933, p. 1196) have studied this phase of the problem and give many references. In other cases, there may be a critical particle size necessary to expose the substance to be dissolved. Very often concentration of reagent may be all important.

For certain types of problem, testing routines have been evolved which keep fixed certain variables that are known to have little effect on the leaching. These are designed to study the effect of certain other variables which do

affect the leaching. In this way the amount of work necessary to determine the best conditions of operation is greatly decreased.

In many instances a knowledge of the solubility of the substance to be dis-

solved is important or a proper understanding of the phase relationship of the compounds involved may be necessary; metastable relationships may be important. A great many solubilities and phase relationships are available in

---

---

### Balance Sheet for LEACHING, DISSOLVING, EXTRACTING, AND PERCOLATING

#### ASSETS

Solubility and phase-relationship data are available for a large number of systems.

Testing routines have been worked out for many types of leaching problem. In these certain variables have been eliminated by experience and only those known to affect leaching are studied.

Laws governing distribution of a solute between two immiscible solvents are well known.

#### LIABILITIES

##### Leaching

Data on phase relationship in which methods of analysis are at all difficult are often lacking.

Variables affecting rate and completeness of solution are so many that almost every problem must be subjected to experimental test to determine optimum conditions.

##### Extracting

Data on partition coefficients rather limited.

Degree of agitation or of subdivision of one liquid in another, required for economic extraction, must be worked out for each problem.

---

---

the reference works and in the recent literature and more are being reported each month. These are certainly a tremendous asset to anyone studying a leaching or dissolving problem.

Many minerals require activating by heat before they can be successfully leached, although theoretically they should be soluble under the conditions imposed. The reason for this is not clear but it appears to be associated with the destruction of the crystal structure by transformation or by loss of some volatile component, generally water. Thus it may be that the heating is in effect a method of comminution and it is the increase in surface area which makes the calcined material more active.

Extracting may be of the leaching type such as the dissolving out of a substance with an organic liquid, or it may be the treating of one liquid with another immiscible liquid to effect a transfer of some solute in the first liquid to the second.

Solubility data are generally not as plentiful in the organic field as in the inorganic and relatively few partition

coefficients are listed in the reference works. The laws governing the extraction of one liquid by another are well-known, however, and so when a problem arises the equilibrium data can generally be obtained experimentally without much trouble.

The remarks made concerning leaching will in general apply to percolation. The method is especially useful when the material to be leached is coarse and when a gas is involved in the reaction.

### Washing

A necessary corollary of leaching is washing. Two principles are used in washing solids, namely, successive dilution and displacement.

The principle of successive dilution is quite simple theoretically and has been applied extensively in countercurrent decantation and in repulping between stages of filtration. If the percentage of liquor which is retained by the solids is known for various liquor strengths, the number of steps required for a given degree of washing may be calculated.

If the displacement principle always operated completely when applied, it would be a simple matter to calculate the quantity of wash required for a cake or drained solid mass carrying a known percentage of solution. However, the situation is invariably complicated by the fact that some mixing and dilution occurs. This may be more or less, depending on the character of the solids; i.e., size, shape and arrangement of the particles, how and when wash is applied, etc. No generalizations have been evolved and the problem must be solved by laboratory or pilot tests.

If the solids are formed by precipitation, proper control of the conditions may give a solid with improved washing characteristics. Careful control of the conditions of separation such as the vacuum on a filter may benefit washing.

Washing of one liquid by another immiscible liquid is essentially an extraction process and is discussed in that section.

Washing of a coarse solid to remove fine solids is a mechanical separation and is discussed under differential settling and screening.

## GAS ABSORPTION

By EDWIN M. BAKER

*Professor of Chemical Engineering  
University of Michigan  
Ann Arbor, Mich.*

PROGRESS has been made in past years in the unit operation, gas absorption, and yet the chemical engineer who seeks to design such equipment is at a loss when he steps beyond a few better known cases. The fundamentals of the operation are well known for the simpler cases, which may be adequately handled by the two-film theory of Whitman [*Chem. & Met.*, Vol. 29, p. 147 (1923); *Ind. Eng. Chem.*, Vol. 16, p. 1215 (1924)], but the newer theory of Davis and Crandall [*J. Am. Chem. Soc.*, Vol. 52, p. 3757 (1930)], for more complicated cases in which reactions take place in the liquid film, needs further testing in the light of data which are not yet available.

Gas absorption may be either isothermal or adiabatic. If considerable heat is evolved on absorption, resulting in contiguous liquid and gas phases being of widely different temperatures, the writer knows of no accepted theory for adequately analyzing performance or designing new equipment.

While many data are available for the rates of absorption of  $\text{SO}_2$ ,  $\text{NH}_3$ ,  $\text{CO}_2$  in water and these and a few other gases in a few aqueous solutions, the data have mostly been obtained on laboratory sized equipment which was frequently of specialized design because of the immediate purpose of the researches involved. Very few data indeed are available on the rates of absorption of gases in large equipment such as would be employed in commercial work. The data of Kowalke, Hougen, and Watson (Transfer Coefficients of Ammonia in Absorption Towers, Bulletin, University of Wisconsin Eng. Exp. Sta., Ser. 68, June, 1925) for the absorption of ammonia in water are a notable exception to this statement. For many systems, including those involved in natural gasoline absorption and solvent recovery, the dearth of information on coefficients, either on laboratory or commercial equipment, is amazing. Thus, while the major design factors are understood, application to particular problems is well nigh impossible. One is not helped in this problem by the fact that a large number of tower packings are on the market and that the physical

characteristics of these packings, such as surface area per cubic foot, per cent free volume, per cent free cross-section, are known. Likewise the pressure drop in packed towers can be fairly satisfactorily calculated, but there are substantially no data available on the maximum permissible vapor velocity in packed towers.

Bubble cap towers and spray towers are available and are now in use in some installations for gas absorption, but little is known generally of their performance. In the case of bubble cap towers theory permits the calculation of the number of equilibrium plates required. For the design of distillation columns some data are available on plate efficiencies, but for the design of gas absorption bubble columns substantially no data are available. Even at best, design by application of "per cent plate efficiency" is unsatisfactory in the sense that this method is not based on the fundamentals of the process, but is rather an empirical method of roughly comparing the performance of two units.

It has been suggested that the application of dimensional analysis to gas absorption theory should prove as help-



ful and as profitable as it has in other unit operations. Little or nothing appears to have been done along this line.

The danger of error involved in extrapolated coefficients obtained with small laboratory apparatus to large towers is pointed out by C. W. Selheimer, Jr., [*Chem. & Met.*, Vol. 41, p. 149 (1934)], who states that in an experimental tower 4 in. in diameter by 20 ft. tall, over 85 per cent of the liquid passing through the tower was collected from the wall surface at the bottom of the tower, only the small remainder being collected from the packing. His recommendation that the diameter of the proposed installation should not exceed ten times the diameter of the experimental tower would eliminate from use in design substantially all of the data now available.

The situation for the unit operation of gas absorption may be summarized briefly in the statement that considerable progress has been made in the matter of understanding the fundamentals of the process, that a few data on laboratory equipment are available and even less data are available on commercial apparatus. Design in the light of present theory and the testing and perfection of

#### FLOW SHEETS FOR CHEMICAL ENGINEERING PROCESSES

To complete the appraisal of unit operations by demonstrating their use in typical industries, an editorial supplement has been prepared, as a second part of this issue, covering the principal operation steps in 42 of the process industries.

theory are dependent on and must await the gathering of more performance data. The writer therefore wishes to present to industry a prospectus of its opportunities to fill in many of the manifest gaps in our knowledge of this art, and thus write off some at least of the liabilities. It is noted that the liabilities consist in large part of the lack of absorption coefficients on commercial apparatus. Were such data available the chemical engineer could compare data on laboratory and commercial equipment, and design with more confidence.

Absorption equipment of all kinds is in continuous operation in many plants. The engineers in those plants, in the

aggregate, could make a major contribution to this unit operation by merely reporting in the current literature an accurate description of the apparatus, compositions and quantities of entering and leaving liquids, with corresponding temperatures and pressures, together with computed "overall" coefficients of absorption. Should plant engineers be willing to gather the necessary data, but not wish to undertake the preparation of papers, they could doubtless find many informed men in the universities with whom they could collaborate. Surely such contributions are in order in this day of "New Deals."

## A PLEA FOR THE UNIT PROCESSES

By D. B. KEYES

*Professor of Chemical Engineering  
University of Illinois  
Urbana, Ill.*

CHEMICAL engineering is based on material flow and energy flow. Up to the present time most stress has been laid on the "chemical engineering unit operations" which consist almost entirely of physical transformations such as distillation, evaporation, crushing, grinding, filtration and absorption. Recently I have called attention to the "chemical engineering unit processes," which involve changes in chemical composition, for example, oxidation, reduction, hydration, hydrolysis and esterification.

It should be noted that both unit operations and unit processes refer to the design, construction, and operation of equipment. The difference between them is that the former involves equipment in which only physical changes take place while the latter employs equipment in which both chemical and physical changes occur.

I believe that the chemical engineer doing development work in industry is more interested in the unit processes than in the unit operations, because the major problems of design, construction, and operation involve equipment in which a chemical change takes place.

Little is known, at the present time, about the fundamental principles of unit processes whereas considerable has been learned in recent years about the less complicated principles of unit operations. This is probably the reason that stress has been laid on unit operations rather than on the more significant "chemical engineering unit processes." I believe that as knowledge is accumulated we will see a complete reversal of attitude on the part of both the teacher and industrial worker in this field.

#### Balance Sheet for GAS ABSORPTION

##### ASSETS

Fundamentals of process well understood for cases where two-film theory applies.

Solubility of gases in liquids known for many systems.

Many data available for rates of absorption of a few gases in water and some aqueous solutions in laboratory apparatus, frequently of specialized construction.

Major design factors well understood.

Characteristics of many tower packings fairly well established.

Pressure drop in packed towers readily calculated.

Bubble cap and spray towers available for gas absorption.

Apparatus has been employed in which gas bubbles are liberated in a body of liquid.

Advantages of absorption under pressure well understood.

##### LIABILITIES

Theory needs further testing where reactions occur in liquid film.

Theory inadequate for cases involving large heat of absorption, resulting in greatly differing temperatures of adjacent gas and liquid phases.

Many data on solubility of gases in organic liquids to be determined.

Few data available for rates of absorption in commercial apparatus.

Many data required for application of design principles missing.

Little known of absorption capacity of packed towers, aside from a few gases in water or aqueous solutions.

Permissible vapor velocities in packed towers not well established.

Little known of performance of bubble cap and spray towers.

Capacity of apparatus in which bubbles are liberated in body of liquid not well known.

Compression of gas is expensive.

# CRYSTALLIZATION

By H. B. CALDWELL

*Swenson Evaporator Co.  
New York, N. Y.*

OUR PRESENT theoretical knowledge of crystallization and our industrial crystallization processes and equipment developed slowly and our practical knowledge is to a large extent empirical. Very few scientists and engineers are concerning themselves with the further development of this subject, either as a science or as an art. One reason for the slow progress lies in the large number of factors to be considered and eventually to be studied before a solid foundation of fact will be available on which to base a complete theory.

The minutiae and fundamental laws of crystallization processes are almost entirely unknown. Venturing beyond the simple statement that crystallization ordinarily requires the removal of heat from a solution, one soon enters the realm of conjecture, qualitative deductions, scientific guess work, and frequently faulty experimentation. Most of the recent advances have centered around economic methods of removing heat.

In general operation three major classifications of crystallizers are available, air-cooled, liquid cooled, and vacuum cooled. These classifications may again be broken down into agitated and non-agitated units, and into continuous and batch equipment. There is frequently also a choice in the mechanical construction of not only the major classifications, but also of the subdivisions. New materials such as homogeneous lead lining, rubber lining, nickel, and clad steels have resulted in low installation and operating costs. Improved efficiency and increased knowledge of design of steam jet vacuum pumps and compressors to produce a given result has been a great boon to the vacuum crystallization field.

To calculate the cooling surface required to remove a given quantity of heat per unit of time, in any type of heat-transfer crystallizer, one should be able to evaluate accurately the following: (a) Temperature difference between solution and cooling medium. This is not the logarithmic mean of terminal differences, as usually more

Capacity factor for various types of crystallizers can be fairly accurately calculated from existing empirical and fundamental data.

Wide variety of designs, including batch and continuous, agitated and unagitated, air-, liquid-, and vacuum-cooled equipment, available for any crystallization problem.

Improved equipment and the addition of many new corrosion resistant materials of construction have resulted in decreased operating costs. Accumulation of empirical data has also made possible a more intelligent selection of equipment and more accurate economic considerations of one type versus another.

Breaking down of consumer prejudice against small crystal sizes has resulted in more economical crystallization methods. A start has been made in accurate control of crystal size and in producing unusual results.

heat is liberated over one part of the cooling range than over the rest of the range. (b) Influence of temperature level on rate of heat transfer. (c) Rate of salting or fouling of the heat-transfer wall and its influence on the rate of heat transfer. (d) Effect of changing magma density and mother-liquor viscosity on the rate of heat transfer and heat diffusion throughout the mass. (e) Effect of velocity of cooling medium, its short circuiting and air binding. (f) Influence of agitation of the solution.

In summation, it appears that the process of crystallization will be for many decades a combination of fundamental and empirical data. Our present lack of knowledge probably handicaps us most in actually controlling the process to produce certain predetermined and uniform sized crystal crops. This should not be considered as a serious state of affairs as most crystals sold today are readily produced in the ac-

## Balance Sheet for CRYSTALLIZATION

### ASSETS

### LIABILITIES

Fundamental laws applying to crystallization processes almost entirely unknown.

Lack of fundamental data, such as solubility and change-of-phase relationships; specific heats of solution and crystals and heat of crystallization over range considered; accurate calculation of heat to be removed.

The following data needed for calculation of required cooling surface: Temperature difference between solution and cooling medium; influence of temperature level on heat transfer; rate of fouling of heat-transfer wall; effect of changes in magma density and mother liquor viscosity; effect of velocity of cooling medium and of agitation.

Little fundamental knowledge exists on crystallization rates in fractional crystallization; size distribution of crystals; nucleus formation temperature; rate and manner of crystal growth and effect of small impurities; effect and use of super-solubility and seeding; critical humidities of salts and size distribution in relation to caking.

ceptable form. The super-solubility idea, undoubtedly, will be employed to build large and uniform crystals in a continuous manner for small tonnages.

Vacuum crystallization cannot help but supplant many existing forms of equipment because of its low initial cost for handling acid solutions, large tonnages, and its inherent ability to reach temperatures below that of the cooling medium. Also where a process requires evaporation as well as crystallization, it is frequently indicated. More data on boiling point rises at various vacuums and further study of entrainment are indicated. It is quite possible that cooling a solution by introducing into it a non-miscible liquid, which vaporizes at the desired temperature, may be employed for certain conditions. Already use has been made of a solution with an appreciable boiling point rise to act as the condensing medium in a barometric condenser serving a vacuum crystallizer.

The author is indebted to W. L. McCabe for some of the ideas presented in this paper.

# EVAPORATION

By M. J. KERMER

Chief Engineer  
Buffalo Foundry & Machine Co.  
Buffalo, N. Y.

**I**N PLANTS where large quantities of water must be evaporated and a considerable quantity of steam is used in the process, the evaporator can play an important part. It is often possible to use the evaporator as a steam producer as well if the material can be concentrated without injury due to overheating.

The use of high-pressure evaporators as producers of process steam only is a field that has hardly been touched and should be given serious consideration, especially in the design of new plants or in cases where new high-pressure boilers are replacing the old low-pressure types. The boiler make-up water for most of the chemical plants varies from 50 to 100 per cent. In a great many cases if the chemical engineer and the mechanical engineer could get together and analyze the existing conditions, this certainly could be corrected to a considerable degree, and in many cases it would be possible to have extra process water available.

The development of the forced-circulation evaporator has played an important part in reducing the initial cost of the equipment when it is necessary to use expensive materials in the construction of the apparatus. This saving is due to the elimination of the hydrostatic-head temperature loss as well as to the improved heat transfer obtained in such apparatus, which results in reducing the size of the heating surface. Similarly the forced-circulation evaporator makes it possible to concentrate delicate materials under close temperature control with the use of high-pressure steam without injuring the material, resulting in a lower initial cost.

The circulating pump used in connection with the forced-circulation evaporator plays an important part in its proper performance. However, it is the weak link in the chain. Due to the high velocity of the liquor through the tubes and the increased viscosity resulting from high concentration, it is inevitable that considerable electrical power is necessary for operating these pumps, and that power costs must be considered in the selection of such equipment. It is sometimes advisable to replace the motor by a steam turbine when it is practical to use exhaust steam for some other purpose.

## Balance Sheet for EVAPORATION

### ASSETS

Improved understanding of what constitutes heat transfer.

Development of new metals and their fabrication to resist corrosive action.

Multiple-effect evaporation can be used.

High-pressure evaporators available.

Evaporator useful as producer of process steam.

Efficient entrainment separators available.

Forced circulation evaporation produces high concentration with low-pressure steam.

Accurate temperature controls are available for concentrating delicate materials.

Liquor level controls dependable and accurate in operation.

Efficient ejectors available for producing high vacuum and removing corrosive gases.

Thermo compressors make possible double effect economy on finishing pans; reduce cooling water requirements.

### LIABILITIES

Incomplete information on physical qualities and characteristics of liquids to be concentrated.

Lack of practical data on corrosion.

Concentrating too high in multiple effect results in reduced capacity.

Improper temperature distribution affects product.

Condensate from multiple effects contaminated by entrainment unsuitable for boilers.

Fouling of heating surfaces retards operation.

In natural circulation evaporators, hydrostatic-head temperature may cause trouble.

Fluctuating liquor levels due to careless operation, may waste and damage material.

Limited knowledge of quantity of non-condensable gases and their distribution through steam belt.

Both the pump and the evaporator designer are in need of accurate data pertaining to the viscosity and specific heats of the liquors to be handled at the various temperatures and concentrations, as well as the latent heat at various pressures. The work by R. J. S. Pigett (A.S.M.E. Process Div., June 6, 1932) on flow of fluids in closed conduits can only be appreciated and applied when the above information becomes available to the engineer in general.

In the field of the natural circulation type of evaporator, the development of the long vertical-tube machine has been advantageous in many respects. Liquor with foamy characteristics can be handled successfully while entrainment losses are at a minimum. It is possible

to install machines with large heating surfaces where floor space is limited, while the design is unusually well adaptable not only for high-pressure work but also permits the fabrication of the more expensive materials. Further investigations are necessary to determine the proper ratio, under different conditions of operation, between the perimeter of the tube on the liquor side and its cross-sectional area.

"Heat Transmission," William H. McAdams.  
"Heat Transfer and Evaporation," W. L. Badger.  
"Studies in Heat Transmission," Allan P. Colburn and Olof A. Houghlin.  
"Progress in Evaporation," W. L. Badger, A.I.Ch.E. "Silver Anniversary Volume."  
"Drop-Wise Condensation of Steam," W. M. Nagle and T. B. Drew, A.I.Ch.E., 1933.  
"Drop-Versus Film Formation," J. O. Jeffrey and J. R. Moynihan, A.S.M.E., Vol. 55, No. 12.



# SUBLIMATION

By JULES BEBIE

Consulting Chemical Engineer  
St. Louis, Mo.

---

---

## Balance Sheet for SUBLIMATION

### ASSETS

Fundamentals of process understood and many necessary data available.

Sublimation offers as advantages:

(a) Production of chemicals with physical characteristics required by trade.

(b) Conversion of crude to refined products in one operation.

(c) Adaptability to continuous operation.

(d) Vaporization at low temperature as compared with distillation.

(e) Small quantities of colored, non-volatile and other impurities can be removed.

Fractionating operations, both in vaporization and condensation, are feasible if required.

Vacuum operation may be employed where applicable.

Temperature regulation during vaporization reliably controlled by various methods of indirect heating.

Satisfactory design methods used.

Equipment sometimes moderate in cost, particularly condensers, and relatively low in operation cost.

Dependable auxiliary equipment available includes steam jet and other vacuum producing equipment, blowers, and control instruments for temperature, pressure and gas flow.

### LIABILITIES

Many needed data and much information on process equipment not as readily available as in case of other more used unit operations, because applicable in comparatively few cases.

Data needed on range of flammable mixtures of air with vapors of substances suited to sublimation.

Fire and explosion hazards are encountered, particularly if air is used in the process.

Where fractionation must be used to obtain a high purity product, uniform and reliable separations are difficult to maintain continuously; degree of fractionation decidedly inferior to that accomplished by distillation.

Condensation of vapors is not susceptible to clean-cut mathematical treatment, because it takes place on variable and additive surfaces.

Large space required for sublimation chambers.

**C**HOICE of subliming as a refining operation is sometimes dictated by the demand of the trade for a product of certain crystalline shape and density. In other cases sublimation offers particular advantages from the standpoint of ease of refining and economy, or it may be resorted to in the refining of products which cannot be distilled without decomposition.

Genuine sublimation, from solid to vapor to solid, is used industrially in only a few cases. Pseudo sublimation, from solid to liquid to vapor to solid, is resorted to in the majority of subliming operations, because most substances do not exert sufficient vapor pressure below their melting points to permit effective sublimation.

Sublimation is usually further promoted by means of a current of inert gas (air, stack gas, CO<sub>2</sub>, nitrogen, steam). A secondary supply of inert gas may be introduced for condensation purposes directly before the gas-vapor mixture enters the subliming chamber. If desirable, the uncondensed gas can be returned to the vaporizing chamber and the operation carried out in a closed cycle to prevent losses from incomplete condensation of vapors.

Fractionating operation of the vaporizing or, particularly, of the subliming chamber must in some cases be employed in order to obtain a product of required purity. In a general way, it may be said that if a pure product is directly obtainable by sublimation, this method of refining has some definite advantages; if, however, fractionating operations are involved and if the product can also be refined by distillation, the latter method is usually to be preferred.

Sublimation under vacuum is applied to advantage in some cases. Recent developments in this field permit operation under very low pressures (below 1 mm.) and are used for large-scale production of metals of high purity, for example, magnesium of a purity of 99.99 per cent. (*Chem. & Met.*, Vol. 36, 1929, pp. 345-7).

Equipment for sublimation is not so well standardized as in some other unit operations and is often specific for particular products or groups of products with which it may be used.

Several systems of indirect heating

have been developed and heat transfer mediums over a wide range of temperature are available.

Welded equipment fabricated of various metals and heating apparatus of the Frederking type have contributed to advances in this field.

A laboratory sublimator for analysis and control has been described in the *Journal of the Association of Official Agricultural Chemists* (Vol. 6, 1923, pp. 481-9).

In its theory and fundamentals, sublimation is analogous to distillation as far as vaporization is concerned, including application of the law of partial pressures. Thermodynamics as applied

to sublimation has been given special treatment (*Chem. Apparatur*, Vol. 16, 1929, p. 139) and a new theory of the rate of sublimation and vapor pressure of solids has been advanced recently (*Trans. Faraday Soc.*, Vol. 29, 1933, p. 794).

So far as the needs are concerned, data for specific and latent heats, heat of sublimation, triple-point pressure and vapor pressure over a wide range of temperatures for many substances are required; also there is need for data on the range of explosive mixtures of air with vapors of products which are actually sublimed or which are suitable for sublimation.

By JAMES S. CAREY

Chemical Engineer  
Alco Products, Inc.  
New York, N. Y.

# DISTILLATION

---

---

## Balance Sheet for DISTILLATION

**A** GREAT PROGRESS has been made in the process industries over the past few years in the realization of higher efficiencies and lower operating costs. Considerable improvement is believed to be possible in many instances in the operation of existing distillation equipment by intelligent analysis of various operations by operating personnel. In view of the data and methods of calculation now available operation by rule of thumb is no longer necessary. Systematic checks, based on plant data ordinarily available, by means of material balances, heat balances, and studies of fractionating efficiency will insure the operation of equipment at its maximum throughput for the products required.

Marketing requirements frequently dictate the adaptation of existing distillation equipment to processing conditions other than those for which it was originally designed. Analysis of the existing installation from the standpoint of the new products to be made will quickly indicate the required changes and the capacity to be expected.

In planning new installations or in bringing old equipment up to date decided operating economies are possible by a wise selection of control instruments from the many well developed types now available. In continuous distillation processes particularly, correct instrumentation will eliminate surges and variations at the key control points, thus permitting the attainment of maximum capacity with small marginal safety factors in excess heat and reflux, or, in other words, minimum overall operating costs per unit of product. Due regard for capacity lags and the relative sensitivity of the several major instruments is important in the selection of the controls for distillation processes. Instruments finding the widest general applications in distillation are flow controllers and recorders, temperature controllers, pressure controllers, liquid level controllers, and the usual recording or indicating pyrometers, thermometers, vacuum gages, pressure gages, and similar apparatus.

Recent developments in certain fields have necessitated the use of higher pressures than heretofore encountered in distillation and absorption equipment. Data

### ASSETS

Fundamentals of process well understood

Operation by rule of thumb no longer necessary in many cases

Process adaptable to large scale operation

Excellent design methods available

Major design factors fairly well established:

Permissible vapor loads for pressure and vacuum operation  
Design and spacing of bubble trays in plate towers

Advantages of vacuum operation being utilized where applicable

Many necessary data are available:

Equilibrium relations  
Heat contents

Minute quantities of impurities removable:

Dehydration of organic substances  
Deodorizing of vegetable oils

Good control instruments available

Efficient laboratory fractionating equipment now available for analysis and control

Well developed and dependable vacuum steam jet ejectors and vacuum pumps now available

### LIABILITIES

Generalizations often difficult to apply in more complex cases

Inadequate data frequently prevents thorough analysis of operation

Cost of small units high per unit of throughput

Design methods for optimum reflux ratio and number of plates become involved for complex mixtures

Limiting vapor loads and hence maximum capacity not well established.

Unexplored possibilities exist in the use of azeotropic mixtures

Undue pressure drop may partially nullify advantages of vacuum

Many data not available:

Liquid-vapor equilibrium relations for complex mixtures

Often a high degree of separation requires disproportionate increases in unit size and operating costs

Improper selection and correlation of instruments may defeat purpose

Prejudices against changes in design as proved in other fields

Process inefficient thermodynamically

Process costly if refrigeration must be used to maintain a two-phase system for fractionation

---

---

on limiting vapor loads for towers of various designs under high pressure conditions are therefore needed by the designing engineer.

Extension of the data available on P-V-T relations of mixtures, heat contents of mixed vapors, and liquid-vapor equilibrium relations, especially as affected by pressure, will all place the designer of distillation equipment in a better position to cope with the varied problems now confronting him.

Extension of the data and correlations now available on condensing vapor film and boiling liquid film heat transfer coefficients will place the design of the vapor condensing and reboiling ele-

ments of distillation units on a sounder basis.

Accurate data on specific heats and latent heats (or total heats) over wide ranges of temperatures and pressures, not only for compounds but also for mixtures, are badly needed.

Extension of the data on liquid-vapor equilibrium relations, particularly in the high pressure region, is of the greatest importance in distillation problems. The work of Lewis (Trans. A.S.M.E., Vol. 54, 1932, No. 17), Brown (*Ind. Eng. Chem.*, Vol. 24, 1932, p. 515) and others on fugacity as applied to equilibrium calculations for hydrocarbon mixtures has furnished much information on the

behavior of these systems. Cummings (*Ind. Eng. Chem.*, Vol. 23, 1931, p. 900) has analyzed the effect of pressure on the equilibrium relations of a number of binary mixtures. Extension of these researches and similar studies for other types of mixtures together with the concurrent study of the relationships of each class of mixtures will fill pressing needs.

A great many data are available on azeotropic mixtures. It is believed that a study of these, together with such new data as may be required, will yield un-

suspected possibilities in performing separations difficult by other means. Specific examples of these applications are the several methods developed for the manufacture of absolute alcohol (Cooley, *Chem. & Met.*, Vol. 34, 1927, p. 725, and Keyes, *Ind. Eng. Chem.*, Vol. 21, 1929, p. 998).

The process industries today utilize the unit operations of chemical engineering in every conceivable combination. Where one of the unit operations, distillation for example, is the major oper-

ation of the process, the equipment will usually be found to be well designed along lines proved by experience in other industries. On the other hand where a particular unit operation plays a relatively minor role in the complete process this piece of apparatus has frequently received little consideration with respect to its design and integration into the process. Rational design and rating of such units will generally result in improved performance and results from the whole process.

# ADSORPTION

By C. L. MANTELL

Consulting Chemical Engineer  
Pratt Institute  
Brooklyn, N. Y.

**P**OSSIBILITIES of adsorbents are little realized. Adsorption processes are most effectively employed as complementary and supplementary to other unit operations. These have definite limits as to small concentrations of materials, where the limits are due to equilibrium, mechanical, or economic conditions. Processing of materials may take place in several steps, each one of which changes the composition in the direction of increased concentration of desired material and decreased concentration of undesired constituents.

When applied to liquids, the methods employed may be chemical or physical and mechanical. Commonly used chemical methods involve precipitation, volatilization, coagulation, or elimination from suspension. The mechanical methods include the unit operations of filtration, settling, thickening, and centrifuging for separation of suspended solids from liquids; distillation and extraction for separation of miscible liquids of different boiling points; centrifuging and settling applied to immiscible liquids of different specific gravities; and evaporation followed by crystallization for the removal of dissolved solids from liquids. Chemical methods are satisfactory when reactions can be economically brought to completion. Organic impurities, because of their complexity, often do not respond to chemical treatment for the removal of color, taste, or odor. These may be readily eliminated by an adsorbent. Filtration, settling, and centrifuging are effective in removing undissolved solids from liquids only when the particles are of sufficient size and larger than the diameter of the pores in the filter media.

Colloids cannot be filtered, settled, or centrifuged out, but may be eliminated by adsorbents. Last traces of miscible liquids are exceedingly difficult to remove by distillation, but an adsorbent in contact with the distillate rapidly reduces the concentration of undesired substances. The purification of soluble crystalline materials can be effected by

solution, evaporation, and recrystallization several times. The procedure is costly, slow, and the yield is poor. Adsorbents are effective in eliminating impurities which are depressants for crystallization and in removing colors and odors in the mother liquor to make possible production of higher purity crystals in greater yields. In removal

## Balance Sheet for ADSORPTION

ASSETS	LIABILITIES
Large number of solid industrial adsorbents with predetermined characteristics available.	Adsorption theory lags behind practice.
Equipment is simple and inexpensive, design factors well established.	Better equipment for revivification of adsorbents needed.
Adsorption processes complement and supplement other unit operations.	In many fields process is non-applicable due to lack of suitable adsorbents.
Most adsorbents either by weight or in terms of adsorption capacity are cheap.	Some excellent adsorbents are expensive.
Adsorbents are effective in small amounts; process is efficient.	Process is inefficient when large quantities of materials are to be removed.
Many adsorbents may be revivified.	Adsorbents are quite specific, selectivity little understood.
Materials of construction of equipment have been tested and constitute no problem.	Many adsorbents in commercial forms are adapted only to one time use.
Duplication of equipment allows continuous cyclic processes.	Little data on mixtures or all-purpose adsorbents.
Process is adaptable to large scale operation.	Satisfactory testing methods lacking.



or recovery of very small percentages of material, adsorptive processes are efficient and have no competitors.

In operation, liquids or gases are brought in contact with solid adsorbents in place, the liquid or gas passing through the adsorbent, as in percolation. In another or contact method, the adsorbent may be mechanically mixed with the liquid and later filtered out or allowed to settle or separated by centrifuging.

Adsorbents have to be tried out on the job; predictions as to what they will do are only of a general nature. Because adsorbents are so selective, processes function around the adsorbent, whose physical form, nature, and properties determine the equipment.

Fractional adsorption processes, corresponding to fractional distillation or crystallization, involving the use of several selective adsorbents, are being developed but to date have found little application. Unexplored possibilities exist.

Equipment design is simple, but design and preparation of adsorbents of predetermined physical, mechanical, and chemical characteristics constitute an important problem only partially solved. The adsorbent is really part of the equipment, but at the same time is a raw material consumed, slowly of course, during the processing of liquids or gases.

Fundamental data relative to capacity per unit weight or volume, retentivity, selectivity, thermal factors involved in, and velocity of the process, exist for some adsorbents but are lacking or are inaccurate for others. These data are slowly being determined and made available. A greater variety of adsorbents would allow the extension of adsorptive processes to a considerable number of applications. More efficient or more highly activated adsorbents, available at reasonable price, are needed. The chemistry and physics of the processes, although much investigated, are not yet

well understood due to the complexity of the problem. Many widely separated data need to be collected, correlated, and interpreted.

Industries employing adsorbents still fail to appreciate the unit operation nature of the process. The equipment is fundamentally the same whether it be used in petroleum, sugar, water, vegetable oils, organic acids, or salt in liquid processing; natural gas, manufactured gas, carbon dioxide, or air in gas treatment. Progress has been delayed because each industry thinks it is special and cannot borrow ideas or transplant equipment from another.

Of the commercial materials, development of fullers earth is static, progress in bone char has stopped, activated carbon is constantly finding new fields and consolidating its knowledge, silica gel is backed by the best collection of technical data, and the relatively new activated alumina is seeking its place in the sun.

---

## DRYING

By **ARNOLD WEISSELBERG**

*Mechanical Engineer, Jersey City, N. J.*

**C**ONSPICUOUS advances in the art of drying during recent years may be traced to the intensity with which the study of the flow of heat has been pursued in the last decade, and which has benefited the art directly. Especially gratifying are the attempts to get at the root of the problems by means of mathematical analyses. They furnish the much needed information on the theoretical relation between the more important variables involved. The mathematical treatment promises to be of real value in the practical solution of drying problems. Newman's moisture diffusivity equations, based on constant values for the diffusivity coefficient developed analogous to those by Lederer and Peek (*Phys. Review*, Vol. 35, March, 1930) for the diffusion of heat have already been successfully used in connection with slow drying products dried under uniform conditions and within ranges not affecting the coefficient of diffusivity to any great extent. More recent investigations carry the mathematical analysis still further with these coefficients as variables expressed as functions of the moisture content.

At present very few data on these coefficients, let alone their functions, are

available. Lumber appears to be the product most thoroughly investigated on this score. Rawley in the United States and Poengen in Europe report on changing heat diffusivity factors with moisture content for various kinds of wood. This information, together with Sonnleithner's data on the moisture diffusivity factor as a function of moisture content have been applied with considerable success by Voigt and Ramspeck, to the mathematical treatment of the drying of lumber.

For a better understanding of the drying mechanism, Sherwood's papers are outstanding among recent contributions. For the designer and operator of drying equipment with a mind for a more scientific approach to his drying problem, Sherwood's suggested approximate formula for the drying rate during the falling rate period when internal diffusion controls, is of real practical value. It permits, in many instances, the close translation of results of investigations on an experimental scale into practical design and operating data. Considering that the prime object of these investigations has been to build up a theory of the mechanism of drying and to find a mathematical proof for it, the

fact that these investigations are based on uniform drying conditions such as are often not encountered in actual drying practice appears to be of secondary importance.

Latest developments in drying technique indicate that there is still a great deal to be learned about its mechanism. They show the want of investigations under changing drying conditions. From such investigations valuable information may be expected regarding factors which would permit increased drying speed during the falling rate period.

Thus the effects of temperature cycles and pulsating ventilation open new avenues for study. Their application is still far from being under control. This is especially important in view of the increased attention to reduction of drying time, the length of which is often responsible for undesirable chemical and biological changes. The economical advantages derived from shorter drying time are obvious.

The question of optimum drying temperatures, especially for organic products, and the relation of these temperatures to moisture content and drying time is receiving increasing recognition; a marked swing to air drying of

the improved kind has resulted. Considerably more experimental proof will be required before the opinions on this score will be brought into closer agreement.

The correlation of drying test data is rendered most difficult by the lack of a definition and test code, plans for which, however, are being laid. Increased use of graphical methods in surveying drying problems is further evidence of the sound engineering methods supplanting the rules laid down by experience.

Humidity measuring and control instruments of the hygroscopic or dry and wet bulb type have been brought to a great degree of refinement, but it is recognized that neither type will ever fill the bill from an absolute point of view. The anhydrant pressure differential type is more promising in this respect, but it is still awaiting commercial development. The same holds true of

drying cabinets for experimental purposes. Those commercially available are far from permitting satisfactory adjustment of the condition of the drying air as required for investigations of the drying process in continuous dryers in which the condition of the air with respect to the moving product changes continually.

Very much felt by those who design or operate drying equipment is the lack of a drying manual in the English language covering both the practical as well as the theoretical knowledge of the art, which would also serve to gather and correlate the scattered data available in various domestic and foreign publications.

Highly efficient air dryers of the continuous type to suit a large variety of products are now available, at low cost compared with that of a few years ago. Lower operating costs, greater drying

uniformity, shorter drying time, dustless operation, and better drying quality have been achieved to an extent not considered possible a short time ago. They are also available in small capacities, thus often competing with the tray batch type of dryer when the production is not too small or too frequently interrupted. The tray batch type dryer promises to regain some of the ground lost to the continuous type in view of recent improvements, one of which is a tray filling device which saves labor and gives greater uniformity. Another is the application of the above mentioned pulsation principle in which the ventilating air is subjected to alternating pressure variations of several inches of water, and by means of which the drying time has been reduced up to one third. The short run, easily cleaned continuous dryer for small batches which is low in cost and can be operated economically is still to be developed. Combining drying and grinding in one operation has proved quite successful in a number of instances here and abroad. It is limited, however, to products which must be dried from high initial moisture and are grindable in the wet state. The great reduction in drying time and its economy give it quite an advantage over other drying methods where applicable.

Improvements in the vacuum dryer field were limited to improved methods of construction and the use of suitable alloys. The continuous type is still waiting for a practical solution. The recent improvement of steam jet vacuum ejectors has led to their wider adoption in vacuum dryer installation. There is a lack of appreciation for the need of a more satisfactory control of the heating medium to prevent overheating of the product in the last drying stages when the reduced evaporation rate is insufficient to cool the product.

High speed drum dryers on which the product is dried in a very fine film have been developed. The shorter drying time with resulting decreased danger of oxidation or other damage, and the fineness of the scraped-off product are the advantages claimed.

With an increasing number of types of dryers available and competing in the same field, the choice of equipment best suited to the particular product more than ever calls for close cooperation between the chemist and the trained engineer. An intelligent selection will not only result in lowering the cost, but in many instances will result in a greatly improved quality of the final product. Unfortunately, in a majority of cases, those responsible for the selection fail to appreciate that the art of drying has developed into a science and that the problems arising must be dealt with accordingly.

---

---

#### Balance Sheet for DRYING

##### ASSETS

Analytical and mathematical treatment of drying has reached an advanced stage.

Close translation of experimental results into practical design and operating data is now possible in many instances.

Importance of correct drying temperatures and reduction of drying time increasingly recognized; new methods for accomplishing the latter, such as forced diffusion and pulsating ventilation being developed and improved.

Plans for codification of definitions and tests laid.

Existing measuring and control instruments for humidity greatly improved. Need for more absolute means of measurement recognized.

Continuous high efficiency air dryers brought to high degree of perfection and their cost reduced.

New air drying equipment offers great selection to suit requirements of product. Shorter drying time and better methods of handling material in dryer account for reduced operating cost, dustless operation, improved quality.

##### LIABILITIES

Present stage of theoretical approach permits only limited application in practice.

Scarcely any data available on coefficients of heat and moisture diffusivity with changing moisture content. Even for constant values of these coefficients much additional data needed.

Theoretical analysis not yet sufficiently advanced to explain fully the mechanism of the methods for reducing the drying time.

Lack of definition and test code hindrance to faster progress.

Humidity measuring and control instruments of the anhydrant pressure differential type still awaiting commercial development. Improved type of drying cabinet for experimental purposes needed.

Continuous high efficiency air dryers for small capacities not yet available.

Advantages of improved air drying equipment not fully appreciated, especially in so far as improvements in quality are concerned.

Drying manual in English on theory and practice needed to correlate data.

---

---

---

# SETTLING SEPARATIONS

By E. J. ROBERTS and G. M. DARBY

*The Dorr Company, New York, N. Y.*

## Differential Settling

A PERFECT classifier might be defined as one which would take a feed and separate into two portions, the finer of which contained no particles coarser than a given size and the coarser of which contained no particles finer than the given size. On a homogeneous material, this is theoretically possible with hydraulic classifiers in which the coarse particles are forced to descend through a rising column of fresh or "hydraulic" water. On a heterogeneous material, it is of course impossible to make the separation in one step. Non-hydraulic classifiers, in which all the water enters with the feed, are theoretically unable to make a 100 per cent clean separation even on homogeneous materials. The fine portion can be made quite free from oversize but the coarse portion always contains more or less fine material.

In spite of this fact, it is mechanical, non-hydraulic classifiers which are used most extensively because of their capacity, flexibility, continuous operation, and uniformity of results. In addition, they require little attention and give a well-drained coarse portion or sand. Furthermore, the mechanical types of non-hydraulic classifier give a coarse portion which is freer from fines than one would expect from theory. This is due to the agitation and draining which takes place in the course of the disposal of the coarse portion.

The general theory behind water classification was studied quite thoroughly by Richards (*Trans. A.I.M.E.*, Vol. 38, 1907, p. 210). A recent summary of the theory is given by Stewart and Roberts (*Trans. Inst. Chem. Eng.*, London, Oct., 1933, meeting).

Considerable theoretical data are still to be desired in connection with classification. Among the items are experimental data on the effect of shape on settling rate, in connection with the separation of mica from clay. Another problem is the effect of degree of flocculation and yield point or "false body" of a pulp on the minimum size of particle which will just move through the suspension.

## Non-Hydraulic Classifiers

Separations anywhere from 10 mesh down to 325 mesh with mechanical classifiers are common practice. Separations finer than 325 mesh (43

microns diameter) are feasible although not common, but will probably be more common in the future. Separations below 5 microns particle diameter have been considered, but as tonnage propositions they are generally not attractive because of the size of the machines involved. In some fine separations a combination of two machines is used; a non-mechanical classifier or "hydroseparator," followed by a mechanical or bowl classifier.

On very fine separations it is absolutely essential to have the suspension perfectly dispersed or else the separation cannot be made. This is a disadvantage when the feed would otherwise be flocculent because a flocculating agent must subsequently be added in order to settle the fine solids.

Closed-circuit grinding is a very important application of mechanical classifiers. On coarse separations the raking capacity, i.e., the capacity of the classifier to handle the coarse portion or sands is very important and machines have been developed to handle very high circulating loads and tremendous tonnages with ease. On fine separations, the overflow capacity is more important and the bowl classifier fulfills this specification.

Auxiliaries have been developed which increase the ease of adjustment of the machines and prevent the accumulation of "critical" sizes in classifiers where separation is 200 to 325 mesh.

The construction may be of wood, steel, concrete or of special corrosion resisting materials.

## Hydraulic Classifiers

Hydraulic classifiers have the theoretical advantage in that they can make a cleaner separation of the coarse and fine material. In practice, however, only the hindered settling type appears to be capable of approaching the theory.

The hindered settling type may also be used to effect a concentration of the denser particles of a non-homogeneous feed if the density difference is sufficient. See Richards (*"Ore Dressing,"* Vol. III, p. 1428; McGraw-Hill, 1909).

In general, hydraulic classifiers use more water than mechanical classifiers, the slime overflow is more dilute, the coarse portion or portions are at a much higher moisture content, and the loss of head on the sands is considerable, which

is objectionable in closed circuit grinding. Also they generally require a delimed feed.

Hindered settling machines are built which require no power except for the water used and are automatic in discharging, although they require a certain amount of attention. On many materials they give excellent results either in closeness of sizing or in concentration of the denser particles. They are used, therefore, chiefly for these two purposes, either in separating 6 to 200 mesh material into a series of closely graded portions or in concentrating the heavier minerals of a non-homogeneous feed.

Jigging constitutes a special type of hindered-settling hydraulic classification. Jigs are primarily concentrators and are useful only when the particles are coarser than 10 to 20 mesh. They require large amounts of water. As with other hydraulic classifiers the degree of concentration depends on the difference in density between the heavier and lighter particles.

## Draining

Draining is closely associated with mechanical non-hydraulic classification since the coarse material is moved up an inclined plane and as it emerges from the solution draining begins. The draining away of the adherent solution aids in removing fines from the coarser particles and this is generally accentuated by spraying fresh water on to the sands. When the sands are fine, such as with a 325 mesh separation, the sprays are atomized and are directed on to the bath so as to avoid disturbing the sands too much.

For ordinary purposes such as closed-circuit grinding, the draining obtained is ample. For operations where the solids are to be subsequently dried or in which it is desired to wash the solids free from adherent solution in as few operations as possible, suction boxes may be used on the classifier deck to dewater the solids still further before they are discharged to the next step.

The rolling and working of the sand as it is moved up the deck aids in eliminating the solution and fines.

Draining has the advantages of low power and labor costs.

The method is most efficient on coarse

(Continued on page 257)



Aerial photo of new plant in  
Corpus Christi, Texas taken  
by McGregor, April 11, 1934



# SOUTHERN ALKALI Pioneers Into Southwest

PROGRESS REPORT AS OF APRIL 15, 1934

By S. D. KIRKPATRICK,

*Editor, Chemical & Metallurgical Engineering*

**C**HEAP POWER at tidewater! Natural gas at a price equivalent to \$1 coal at a plant site on deep water convenient to raw materials and a growing market. That, in a few words, is the reason that Corpus Christi, Texas is today the scene of one of the most interesting chemical developments of recent years. At least \$6,000,000 is being spent by a jointly owned subsidiary of the Pittsburgh Plate Glass Co. and the American

Cyanamid Co. in a modern ammonia-soda alkali plant which promises to be the first in commercial operation in the great Southwest. It is undoubtedly the forerunner of other chemical industries that will eventually be attracted by the same economic factors that brought the Southern Alkali Corp. to this growing territory.

Later, this story of plant location with its important bearing on future trends in chemical industry will be

told in detail in these pages. At the moment, it is our purpose to report by word and picture on the progress of this great project at the time of the writer's visit in the middle of April, 1934.

Although the project has been "on the drafting board" for three and a half years, it was not until July, 1933, that ground was actually broken. Since then, between 600 and 1250 men, mostly recruited from the neighborhood, have

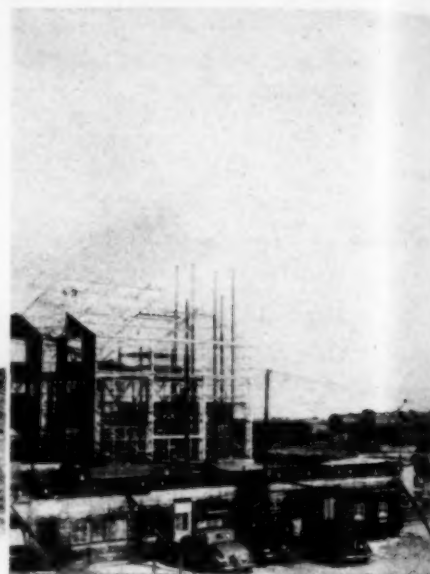
transformed the gentle slopes of Avery Point, just west of Corpus Christi into a scene of intensive industrial construction. A plant site of 65 acres of the total holdings of 350 acres is being rapidly developed into the most modern type of chemical plant construction. It is indeed a stimulating sight to see such a program moving forward in a dozen different directions, yet all geared to a single objective, namely, the commercial production of basic alkalis by September 1, 1934.

As clearly shown by the accompanying aerial view, the plant site is to be adequately served by both rail and water. Three miles of spur track and railroad switches parallel the major axis of the plant and converge into the main line of the Missouri Pacific System. Perpendicular to the shore line at the plant site, a 450 ft. by 100 ft. pier is being built which will be capable of handling two ocean-going vessels at a time. A new 30-ft. channel is being dredged which will extend the present basin from in front of the city docks, westward for 7,500 ft. where it will end in a new turning basin 1,600 by 800 ft. Above the pier is to be erected a dock house, 50 ft.x300 ft., for storage of finished products and served by a single portal Gantry crane loading goods directly from freight cars into vessels. Beneath the pier is the pumping station, where large electrically - driven centrifugal pumps will handle the 25,000,000 gal. per day of sea water required for cooling purposes in the plant.

Principal raw materials for this plant are salt brine, limestone, oyster shell and coke. The salt will be obtained from the company's own wells on the Palangana dome in Duval County, the seat, incidentally, of the Duval Sulphur Co. Although 61 miles from the alkali plant site, the disadvantages of



Assembling Absorbers  
for Process Building



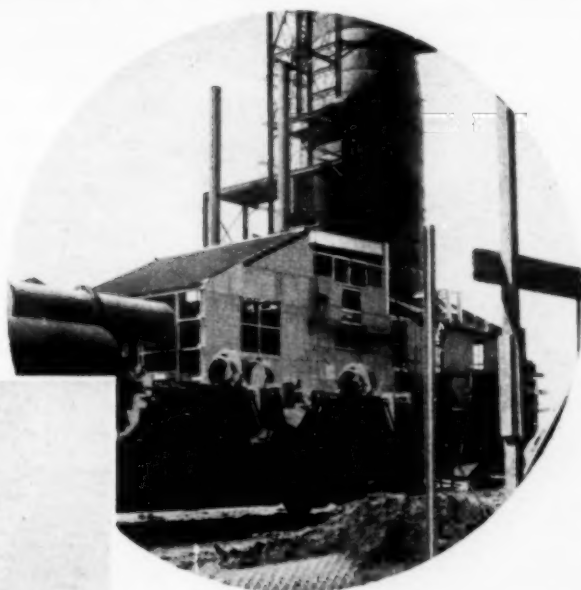
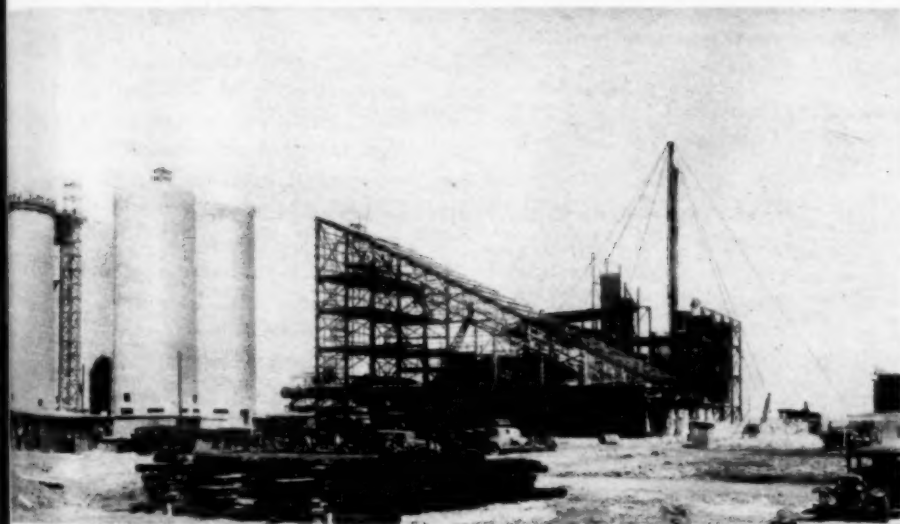
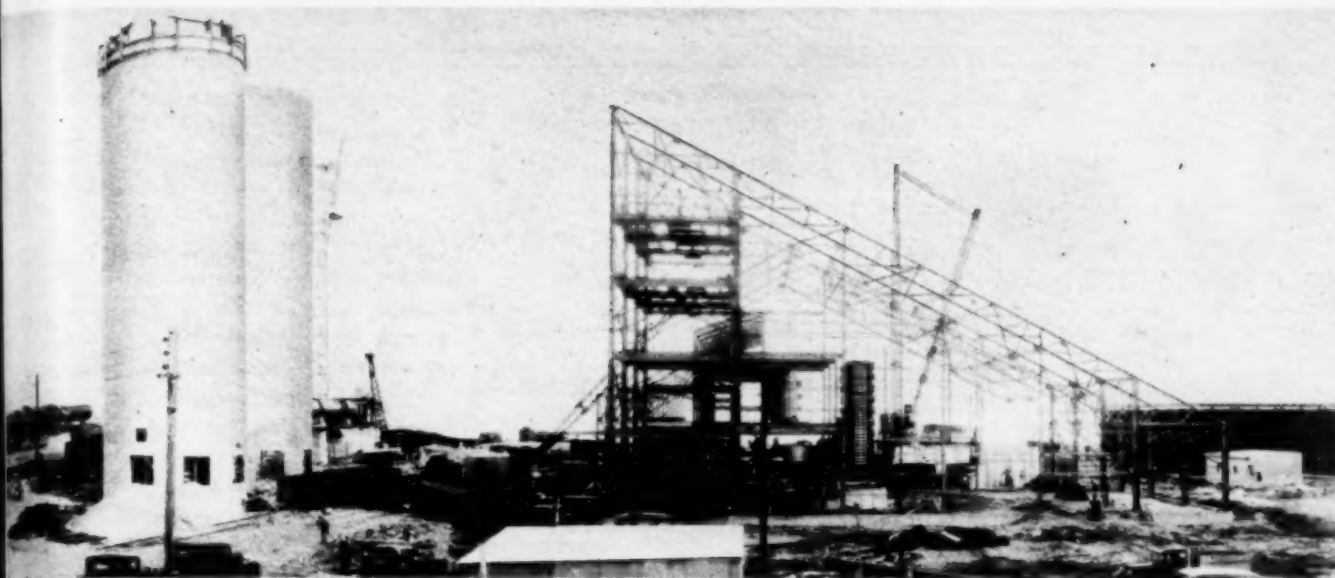
Monthly Stages in the Construction Program at Corpus Christi  
At Top, as of Jan. 25; center picture taken Feb. 15; below,  
status as of March 15, 1934

such a distance are largely offset by the fact that the salt dome is at a sufficient elevation above the plant site as to permit of gravity flow and thus obviate the necessity for pumping the brine. The new pipe line, almost com-

pleted at the time of my visit, is of 14 in. cast iron pipe, mechanically jointed. It discharges the brine into the 3,000,000 gal. open reservoir shown at the right in the plant view.

Limestone and coke will be shipped





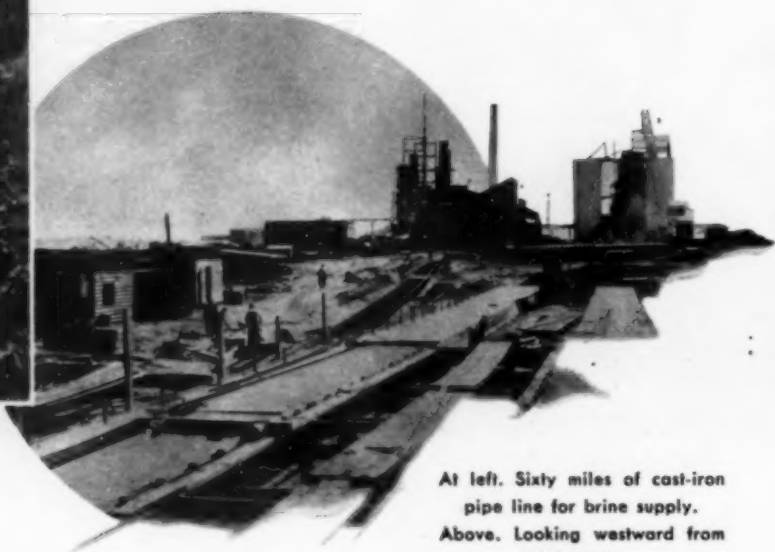
Vertical lime kiln and slaking equipment

to the plant by rail, the former from quarries on the Balcones Fault and in the New Braunfels area near San Antonio. The coke is shipped from the smelters at Eagle Pass or from the Birmingham district. Oyster shells, which will be used as a source of lime for causticizing the soda-ash, are present in abundance in the sunken oyster reefs just across Nueces Bay from the plant. Shell will be excavated by a dredge, washed and delivered to the shell dock for storage ahead of plant requirements.

The natural gas properties owned by the Southern Alkali Corp., are in the midst of a developed field about 6 miles west of Corpus Christi. Available at the field at pressures in excess of 2,000 lb., the gas will come to the plant through an 8-in. welded steel pipe line. Fresh water for boiler and process use is obtained from the city's water treatment plant at Calallen on the Nueces River about 13 miles west of the city.

As viewed from the east end of the plant, we see at left the evaporation building where a part of the caustic soda will be finished in the gas-fired caustic pots of Goslin-Birmingham manufacture. These are followed by flaking and grinding equipment and alongside of this building is the drum





At left. Sixty miles of cast-iron pipe line for brine supply.  
Above. Looking westward from the docks

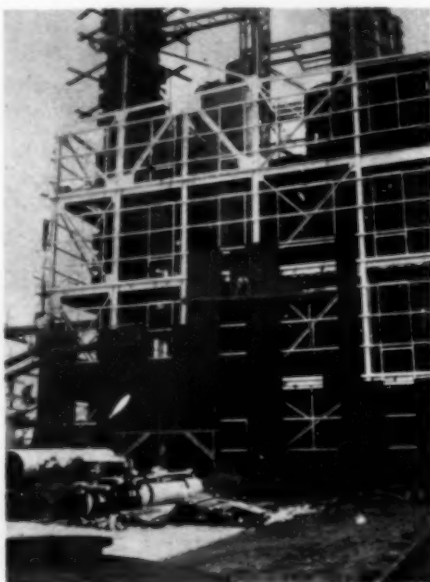
house and storage tanks for liquid caustic soda. Ahead of it, to the west, are the evaporators, Swenson "quads" with pure nickel tubes and Ni-clad bodies. Goslin-Birmingham also supplied the jet condensers; Worthington the large vacuum pumps. The causticizing plant, with the Dorr thickeners and bowl classifiers, lies between the evaporators and the rotary kilns in which shell is to be calcined.

The large building in the center of the picture is the machine shop, said to be one of the largest in any southern industry and adequately equipped to take care of major as well as minor repairs. A general line of large capacity machine tools, electric and gas welding and cutting equipment, boiler and sheet steel repair shops and a large storage warehouse, all are served by an overhead traveling crane.

Next in view (in the aerial photograph) are the four concrete silos for storage of soda-ash. These are provided with equipment for bagging the

product and bulk car loading at the silo base. Behind the silo is the huge vertical kiln in which the limestone, stored in underground bins beneath the tracks at the left, will be burned for gas and lime. The heavy castings for the stills and absorbers were just being put into place in the process building at the right, at the time of my visit, while the dryers and kilns

Protected metal siding goes into place on process buildings.



for calcining are to be housed in the building opposite the silos.

In the foreground, marked by the impressive stack which rises 220 ft. from its base of 36 ft., is the power plant where the Babcock & Wilcox Sterling type gas-fired boilers furnish steam at 450 lb. Power is supplied by two large Westinghouse turbine generators of the extraction type, delivering at low pressure the large quantities of steam required for process use. A central station switching control is provided adjacent to the turbines to complete the electrical services of the plant. Standby electrical transmission lines tying in with those of the local power company provide assurance of continuous operation.

The plant is adequately protected against fire by a system of watermains and hydrants—one of the first steps in the construction program. The buildings are of steel, protected with aluminum paint. Sides and roofs are of Robertson protected metal, their black surface forming a vivid contrast to the white concrete of the stack and the storage silos.

Another unique and attractive feature is the office building and laboratories now under construction at the southwest corner of the plant. The building, of brick and stucco, is of Spanish architecture in keeping with the fine residences of the area and yet eminently practical in its provision for executive offices, dining room facilities, clinic and dispensary. The entire left wing will be given over to the control and research laboratories.

The construction work is being consummated through a joint organization of the Southern Alkali Corp. of which O. N. Stevens is general manager, and the construction engineering firm of the H. K. Ferguson Co. of Cleveland. The writer desires to express his appreciation to Mr. Stevens and to Mr. S. Maston Nixon for the courtesies shown during the visit to Corpus Christi.

---

---

**Balance Sheet for**  
**DIFFERENTIAL SETTLING (Classifying)**  
**Non-Hydraulic**

**ASSETS**

Mechanical classifiers available for size separations from 10 mesh to 325 mesh or even finer.

Such classifiers operate continuously with little attention to give most uniform results.

Operation of mechanical classifiers is very flexible, adjustments are simple and the equipment does not get out of order easily.

They produce a coarse portion which is of low moisture content, much freer from undersize than general theory would indicate and, therefore, make possible efficient closed-circuit grinding.

Oversize from classifiers is elevated and this renders auxiliary elevating equipment unnecessary if units are properly laid out.

Machines are available in almost any construction for corrosive solutions; in sizes to handle up to 12,000 tons per day of sand load; and in proportions to handle almost any ratio of coarse to fine in feed.

Theory is quite well understood.

**Hydraulic**

Hydraulic classifiers of hindered settling type can produce a series of closely sized products from 6 to 200 mesh on homogeneous feed.

On heterogeneous feed, if difference in density is sufficient hydraulic classifiers can effect considerable concentration of the heavy material.

Such classifiers require little or no power except for water used.

Theory quite well understood.

**LIABILITIES**

Due to extremely slow settling rate of particles smaller than 5 microns, size of equipment for such separation becomes inordinately large.

Due to theoretical limitations, coarse portion is not 100 per cent free from fines even on homogeneous material.

Due to pseudo-plastic nature of flocculent pulps, a deflocculating agent must often be added for fine separations; this must subsequently be counteracted before clarification.

Hydraulic classification requires large quantities of water, especially when free settling. Coarse portion is not drained and fine portion is at high moisture content.

There is considerable head loss through machines with respect to coarse portion. Feed must not contain too much very fine material.

Machines must be built in rather small units to secure proper distribution of water.

---

---

(Continued from page 252)

material, say, 10 mesh, and becomes less so as the fineness of the sand increases. When the sand is around 325 mesh in size, it becomes difficult to rake and the moisture content is much higher. The coarser the sands are the faster they can be raked and a much steeper slope can be employed.

Draining may also be done by various batch methods such as piling the material in heaps and allowing it to stand, use of nutschs, etc., but generally some continuous operation, as in mechanical classifiers, is more economical.

**Flotation**

Flotation has slowly been gaining ground in the chemical field. The flotation of certain non-silicate calcium compounds such as fluorite, calcite and phosphate rock has been fairly well developed. Other uses of the method are few and far between. The principal difficulty lies in finding reagents which will float the compound desired and

which will be selective in their action.

The mechanical means for carrying out the operation are numerous; different machines have different advantages and special uses in the metallurgical field and will probably be adopted in the chemical field as needed.

**Tabling**

Concentrating by means of tables and vanners appears to be restricted chiefly to the metallurgical field at present. The specific gravity of the denser particles must be at least 1.0 and preferably 3.0-4.0 greater than that of the lighter, for efficient separation. These limitations necessarily restrict the scope of application of the method in the non-metallic field to a very few compounds. In many instances in the metallurgical field, the use of a closely sized feed such as is produced by a hindered settling classifier, has made tabling advantageous where it otherwise would not have been.

There are a number of well developed machines available.

**Straight Settling**

CERTAIN mechanical separations have as their object either complete separation of two phases or the concentration of one of the phases to a degree suitable for the next operation. Where the phases are liquid and liquid or liquid and solid and the particle size or state of agglomeration of the disperse phase is such or can be made such that the action of gravity causes a reasonably rapid separation from the main body of the dispersion medium, a separation or concentration of the disperse phase can generally be made by gravity settling. Such a concentration often suffices, the solids being in a suitable condition for the next operation, or the concentration by settling may well be an advantageous preliminary to further concentration by filtration or centrifuging.

Gravity settling when operated in continuous manner has the advantages of very low power and labor costs. Only when space is at a high premium or when the settling is slow and the

---

---

## Balance Sheet for STRAIGHT SETTLING

### ASSETS

Through use of settling, suspensions varying from less than 1 per cent solids to 30 per cent solids may be concentrated to from 5 per cent solids to 66 per cent solids.

Testing methods available for calculating capacities of commercial settling units.

Sludge from continuous thickeners almost invariably lower in moisture than that from batch operation. Underflow concentration of solids may be further increased in some cases, using special mechanism.

In certain fields, feed pretreatment has received considerable study; efficient mechanical flocculators developed to aid chemical dosing.

By means of a series of settling operations interpolated with repulping in weaker liquors, solids are washed efficiently.

Storage of pulp in thickener often advantageous in ironing out fluctuations in amount and character of feed and in providing storage.

Equipment thoroughly mechanized, requiring almost no attention for continuous, uniform separation of liquid and concentrated sludge.

Compact units with superimposed trays may be used in parallel for additional settling area; or in series for washing, giving saving in floor space, fewer pumps and simplified operation.

Power required very small; machines available in wide range of sizes; ordinary or corrosion resisting construction.

Smaller machines can be insulated for small temperature drop.

### LIABILITIES

Sometimes sludges settle so slowly as to require a machine inordinately large in proportion to quantity of material treated; control of solids formation sometimes avoids this difficulty.

Concentration of underflow obtainable often limited by its pumpability.

Overflows from very dilute suspensions not always as clear as desired; proper pretreatment or flocculation for good clarification often difficult to determine.

Feed pretreatment in general barely touched; complex nature and colloidal properties of suspensions will make advance necessarily slow.

Occasionally, with limited wash water and high solution content of sludge, number of thickeners required for efficient washing is prohibitive.

Very small units, especially if not run continuously, may take considerable care in operation.

Much basic theory of settlement and general behavior of flocculent pulps still undeveloped.

---

---

concentration small do other methods become more economic. The machines for carrying out the settling continuously may be built of almost any material necessary to withstand the action of the solutions handled. A considerable number of rubber lined tanks equipped with rubber covered mechanisms are in operation. The tanks may be covered and insulated to reduce the heat losses on hot solutions. The mechanical features relative to the different sized units have been pretty well worked out, although improvements are continually being made.

A continuous thickener with continuous discharge of sludge will give a higher concentration of solids in the underflow than would be possible with batch operation; in fact, the concentration is often limited by the pumpability of the underflow.

Where applicable, superimposed units or "tray thickeners" save space and reduce the cost and care of operation. These are especially advantageous in the chemical field where space is costly and heated solutions are being treated.

Although testing methods have been developed which allow accurate calculations of sizes of commercial units from simple laboratory tests, the basic theory

of the settlement and general behavior of flocculent pulps is very much in its infancy. Stewart and Roberts (Trans. Inst. Chem. Eng., London, Oct., 1933, meeting) have recently discussed the situation together with some of the complicating factors involved. Stokes law and the work of Richards (Trans. A.I.M.E., Vol. 38, 1907, p. 210) are ordinarily of no use in connection with the separation of solids from liquids, since in order to get a satisfactory clarity of overflow the pulp must be flocculent. In the separation of two immiscible liquids, Stokes law (modified to apply to a liquid particle) probably holds in all cases, although here again the suspension must not be stably dispersed or else the very fine droplets of the disperse phase will not coalesce to attain a high enough separation velocity and the discharge will be contaminated with the other liquid.

One of the chief developments of the past few years in the subject of settling has been in the pretreatment and conditioning of city and plant water supplies before clarification and filtration. Presedimentation with controlled turbidities going to the main flocculation basins is practiced in a number of plants. Closer control in chemical dosing of the

water, together with the use of mechanical flocculators, have added to the efficiency of the clarifiers in a large number of plants. More accurate and detailed presentation of the data of the various existing plants would aid in progress along these lines.

The problem of trade waste is becoming more acute all the time and the handling of these waters often requires careful study before prescribing the treatment and determining the size and type of equipment to be used. Here too there is a lack of desirable data.

Unless too high a ratio of poorly settling solids to liquid is produced in a given process, the solids can generally be washed free from the liquid product in a series of settling tanks, either separate or in one unit, constituting the sequence known as countercurrent decantation.

In some instances solids are produced in a chemical reaction which settle so slowly that it is not economic to handle them in a settling apparatus. Certain changes in the method of carrying out the reaction without altering the chemical characteristics of the product may result in such an improved behavior of the solids in settling and thickening that this method is quite feasible.



# SEPARATION OF GAS DISPERSOIDS

By EVALD ANDERSON

*Western Precipitation Co.  
Los Angeles, Calif.*

WITH FEW exceptions little experimental work is being undertaken these days on the many problems in connection with gas dispersoids and in the development of apparatus, most manufacturers and engineers following existing design or making poorly considered designs.

An inspection of settling chambers, built by plant engineers, often reveals an almost complete lack of understanding of the importance either of providing minimum settling distances, or of maintaining uniform gas flow. Probably not one engineer in a hundred takes the trouble to determine the settling rate of the dispersoid before proceeding

with the erection of the settling chambers. The complaint of the smelter men in Freiberg, Saxony, in 1838, of the poor results from settling chambers, was probably largely due to poor engineering. Poor results are often similarly caused today.

To America goes the credit for inventing the most useful and most commonly employed centrifugal apparatus, the cyclone, which was apparently first put on the market in the eighties by the Knickerbocker Co., of Jackson, Mich. But until lately, little has been done to obtain a real understanding of its action. Inventors a plenty have suggested modifications, nearly all apparently based

on hunches rather than on any real study of the problem. It is astonishing that so simple, although important, a matter as the relation between tube diameter and size of particles collected has evidently received no attention until comparatively recently.

Many other types of centrifugal apparatus are still built with many units in series, even though it must be obvious that if the centrifugal force in the first unit will not separate a particle, the chances of doing so in succeeding units are poor.

Aside from the electrical precipitation method, the filtration method has been by far the best developed. Since the first

---

---

## Balance Sheet for SEPARATION OF GAS DISPERSOIDS

### ASSETS

Stokes' law and its modifications quite accurately specify relation between size, weight, and resistance to motion in the gas, of dispersoids of the size range usually encountered in industry.

Work started on determination of amount of electrical charge that particles can assume in ionizing atmospheres.

Apparatus, though not yet simple and direct, now available for particle size determination.

Beginning made on accumulation of size-data.

### LIABILITIES

Data scattered, and not easily available.

Degree of applicability of Stokes' law in moving gases unknown.

Little known about:

- (a) Electrical charge of dispersoids and its effect on separation.
- (b) Factors affecting formation of condensed dispersoids, such as vapor concentration, time, and supersaturation.
- (c) Effect of water vapor on the behavior of dispersoids, the factors determining agglomeration, or the factors governing the adhesion of dispersoids on surfaces.

Practically no data available on size distribution of industrial gas dispersoids.

### Gravitational Methods

Stokes' law and some available empirical data permit design of proper apparatus.

Fundamentally correctly designed apparatus available, as the Howard dust chamber and the "Wiest Staubkammer."

Ignorance of fundamentals, apparently, is responsible for many high, narrow, inefficient chambers, with little thought given to uniform gas flow; baffle apparatus confounded with settling chambers.

No easily available data on settling rates, and size distribution of dusts, nor on effect of turbulence and heat convection currents in chambers.

### Inertial Methods

Cyclone collectors well developed, mostly empirically, and easily available; start made to a better understanding of fundamental problems involved. Baffle chambers, particularly for wet collection, also fairly well understood.

Little known of fundamental theory of centrifugal apparatus.

No general understanding of relation between gas volume capacity, resistance or pressure drop, and collection efficiency.

Practically no data available for specifying apparatus for separation of a dispersoid of given particle size and density.

(Continued on page 260)

### Filtration

Method simple and well understood.

Excellent apparatus available, both simple bag houses and automatically cleaned bag filters; cloth developed for considerable temperatures and fairly corrosive gases.

Filtering medium, as adaptable and efficient as cloth, to withstand higher temperatures and more corrosive gases, not yet developed.

### Spray Methods

Simple baffle scrubbing towers, extensively used and sometimes fairly efficient.

Design of nearly all apparatus based wholly on empirical data, or on guesses.

Design of packed towers well understood. Many types of wetted filters, or filters coated with adhesive material, available. Disintegrator type of washer highly developed and efficient.

Large number of very inefficient apparatus in use, due to lack of intelligent design.

### Electrical Precipitation

General basis of process well understood.

Theoretical basis of process not yet completely established.

Apparatus available for practically complete separation and collection of any dispersoid, from unfilterable bacteria to particles dispersed at high temperature or containing corrosive constituents.

Data needed on:

All developments and improvements available throughout the world; large proportion of returns used for development of process.

- (a) Rate and extent of ionization of dispersoids in known ion-atmospheres.
- (b) Rate of motion of "ionized" particles in electrical field.
- (c) De-ionization of transported particles.
- (d) Better means for rendering particles conducting.
- (e) Electrical characteristics of large aggregates of discharge units.

bag house, which was probably that developed by Karl Möller in Germany, also in the eighties, these have been made more and more foolproof and efficient. In the so-called "mechanical" filters, with their automatic shaking, the art has progressed to the greatest extent. From requiring as much as 4 sq.ft. of filtering surface per cu.ft. per minute in the old bag houses, many of these filters now take less than  $\frac{1}{4}$  sq.ft.

Of all mechanical methods for the separation of gas dispersoids, the spray method is perhaps the most common. Stockoe, in England, invented the baffled spray chamber for smelter gases in 1845, but since this time innumerable spray or washing chambers, must less efficiently designed, have been installed by engineers. It does not speak well for his training that frequently the college-trained engineer still seems to believe that passing a dust-laden gas through a large chamber equipped with a few coarse sprays can bring about contact between the large drops and any fair proportion of the minute gas-surrounded dust particles; or, that passing such a gas through water in large bubbles will wet the dust particles in the interior of the bubbles.

Of all processes for the separation and collection of gas dispersoids, the electrical precipitation process is by far the most interesting, and important. It is universally applicable because, given apparatus of the proper size, it can efficiently separate particles of almost molecular dimensions which would pass

through the finest filter. With the modern high-temperature construction materials, it will remove dust from gases at almost white heat.

Equally interesting is its original and later development. The process is associated throughout the world with the names of F. G. Cottrell and Sir Oliver Lodge. While he was a professor of physics at the University of California, working quite independently of Sir Oliver Lodge who had carried his development to a commercial size apparatus, Dr. Cottrell developed the process to a point perhaps more advanced than it had reached elsewhere, for which reason his name is now associated with it everywhere.

Prof. Cottrell was and is an idealist and conceived the idea of devoting the profits from the working of the process to the furtherance of research, dedicating a large part of his patent rights to the Research Corp. under the aegis of the Smithsonian Institution. Through the able management of this corporation an organization has been built up adequate to handle all the various problems encountered; and the proceeds of the operation now help to support such varied research activities as plant behavior at the Smithsonian Institution, development of high voltage apparatus, at Massachusetts Institute of Technology, and atom-smashing at the University of California.

Some of Dr. Cottrell's students have carried on his policies where he left off. Thus, Walter Schmidt is now president

of Western Precipitation Co., having acquired certain territorial rights for the process from Dr. Cottrell. He too has devoted by far the greater part of the returns from his business to the development of the process. Indeed, some of the most essential developments in the present art came out of his laboratories.

In this way, electrical precipitation for separating gas dispersoids, although by far the most perplexing and complicated of all such processes, has been developed further and is now on a much firmer basis than almost any of the others.

## DIALYSIS

By H. M. POWELL

*The Lilly Research Laboratories  
Indianapolis, Ind.*

[Dialysis is a little known unit operation, employed in a few manufacturing processes for the separation of crystalloidal solutions from colloidal materials, making use of the permeability toward the former of certain animal and vegetable membranes. Dialysis has been used to a considerable extent in Europe for the recovery of steeping caustic in rayon manufacture, where it is employed to eliminate hemi-celluloses. This application is now receiving increasing consideration in the United States. The only other commercial application now

known to be in use is in the production of certain biologicals, as the author has described below.—*Editor*]

**C**LOSE ASSOCIATION of both antigens and antibodies with protein substances having well-known salting out properties has led to the routine separation of such immunological agents from rather complex protein mixtures in which they appear.

Following the salting out, the salt or salts are commonly removed from the preparation by dialysis through semi-permeable membranes. In large scale production, dialysis is either conducted against tap water or distilled water, and while the "last rest" of salt is quite difficult to remove even on prolonged dialy-

sis, a reasonable removal of salts through cellophane or parchment membranes may be brought about in two to five or six days. Arrangement of dialyzing bags to present greater surface, such as exhibited by envelope-shaped bags, facilitates the operation.

It may be mentioned that in the dialysis of anti-serum and other similar agents for human treatment, it is necessary to control conditions at least as well as in the case of perishable human food materials. It is urgent, therefore, that bacterial contamination and proteolysis be prevented. Precautions may be observed by the use of chemicals known to inhibit bacterial growth, or the use of temperatures sufficiently low to prevent growth, or both.

A heterogeneous mixture such as the feed to a filter must necessarily be, is not subject to exact formulas of control as are steam and compressed air, or elementary liquids such as water.

Finely comminuted mineral substances, derived from grinding ores and minerals, produce particles of irregular shape; the most skillful sizing by hydraulic or screening methods still leaves a multitude of different size particles in the finished pulp destined for filtration. Chemical precipitates are similarly irregular, while organic substances in filter feed are even less uniform in size. Fortunately, careful study of samples under test conditions furnishes a reliable method for gaging and anticipating the performance of filters under normal operating conditions.

It is this irregularity of physical form for which the modern filter has been perfected for cake formation and washing. Filters today combine the necessary and desirable features of continuous operation, compactness per unit of capacity, ability to form and discharge solid residues continuously with minimum moisture content, and to wash these residues to a minimum of retained soluble value, using a minimum of wash liquid.

## FILTRATION

By D. F. IRVIN

*Oliver United Filters, Inc.  
New York, N. Y.*

**A**N ACUTE need for filters for handling finely ground gold ore in the development of the cyanide process caused very rapid advance in the design and use of filters for large tonnages. As inventive thought and operating skill were concentrated on the problem practical, cheap, and efficient units were rapidly perfected in this heavy tonnage application. Technical advance, therefore, probably developed faster than if it had been confined to small batch processes in lesser industries.

Shortly after this period, during the years of the World War, another great stimulus to plant methods resulted from the huge increase in productivity which promoted a wider use of filters.

From the earliest simple forms of filters, hardly more than strainers, we have now progressed to filters for surprisingly wide ranges of temperatures, pressures, pulp dilutions, and particle dimensions.

Corrosive liquids, such as the concentrated acids and alkalis, can now be handled successfully in modern filters by the aid of new materials of construction and new filter media.

Accessory elements in filtration are highly important and deserve extensive study. Among these may be listed the use of filter-aids, coagulants and solvents. Though much has been accomplished in the study of these accessories a great deal yet remains to be done and some of the brightest chapters in the art may be written under those headings.

---

---

### Balance Sheet for FILTRATION

#### ASSETS

Filtration important in most of process industries; many employees trained in operation.

Careful testing of representative samples makes possible close estimation of filter requirements and performances.

Filtration operates well under all conditions of temperature and pressure; with thin and thick pulps.

Modern filters permit thorough washing of pulps impossible to attain by other methods.

Wide range of construction materials and filter media available.

Filter manufacturers persistent students of all problems involved.

Labor and power cost have reached a minimum.

#### LIABILITIES

Shape and size of solid particles in filter feed non-uniform.

Cake deposition on filtering surface and rate of filtrate flow not yet subject to rigid physical control.

Filter feed suspensions can never be homogeneous substances with definite characteristics.

Cake formation influences filter performance. Size and variable nature of particles affect cake formation.

Filter media influenced by solids in the feed; no universal filter medium known. Proper choice of medium determines results.

Further investigations of materials of construction required; fuller knowledge of solvents, filter aids, and coagulants should greatly increase scope of filtration.

Supplies cost worth studying in some cases.

---

---



# MAGNETIC SEPARATION

By G. W. JARMAN, Jr.

President  
Separations Engineering Corp.  
New York, N. Y.

**T**HE WORDS "magnetic separation" have always meant to the layman the use of some device which will remove magnetic objects mixed with desired materials. Customarily, the thought has been that magnetic separators were used as extractors of tramp iron, nuts and bolts, and other misplaced or mislaid gadgets. However, as engineers know, this is not the whole story. As a result of considerable work done between 1885 and 1905, a separator was manufactured to concentrate ores and minerals which would respond to the strong magnetic attraction created by the machine. This equipment fell short of the desired mark in many cases and it is only as a result of recent research that new forms of high-intensity magnetic separator have been developed.

Every material has an inherent magnetic susceptibility, just as it has an inherent specific gravity. Because the susceptibility varies for unknown reasons, however, it is not as easily determined, nor as readily predicted as specific gravity. It cannot be picked out of a table of physical properties of compounds as can the other invariable properties of materials. Materials that look alike and show identical chemical analyses, but come from different parts of the world, may vary to an incredible extent in magnetic susceptibility.

It is on the basis of variations in magnetic susceptibility that separations are accomplished by this unit operation. When the differences between the components of a mechanical mixture are sufficient, then magnetic separation may be an economical means to employ, especially if the specific gravities are too close together for separation by other mechanical devices. The latest magnetic separators have been able to go far down the scale of susceptibility and select between materials which, to the layman, are not magnetic at all. Thus, take the case of feldspar which contains mica of both the biotite and muscovite types. A few years ago it was possible to remove the biotite or black mica by magnetic means, but now it has been found that the high intensity machine can also effect a separation of the white muscovite. Again, in the case of such seemingly non-magnetic materials as ash in coal, iron and silica in bauxite, gangue in pyrolusite, and impurities in

apatite, the high-intensity method has effected excellent separations.

The production man can well afford to look into the magnetic handling of materials. He is, of course, acquainted with the protection which a magnetic pulley gives to his crushing machinery. He appreciates that he must install a pulley large enough to take care of the largest bits of tramp iron that might be encountered. He also must realize that at high rates of flow, say 200 tons of coal per hour, small particles such as a shingle nail will frequently not be held even by a powerful pulley. Often he has

to decide between magnetic separation and some other mechanical means of concentration. In figuring costs in comparison with flotation, for example, he must give credit to the magnetic concentrator for the fact that it does not require such fine grinding.

Having decided on magnetic separation, the engineer must then consider wet against dry magnetic separation. The choice will generally be fixed by the type of ore to be treated, inasmuch as wet separation has limits in magnetic susceptibility which are, broadly speaking, those of iron and magnetite re-

## Balance Sheet for MAGNETIC SEPARATION

### ASSETS

Magnetic separation capable of treating materials of variable composition.

Operating and power costs very low, i.e., for the latter, about 0.5 kw.-hr. per ton.

### Magnetic Pulleys

Protect machinery by removing tramp iron with low-cost pulleys.

Size limit on objects removed, dependent both on pulley size and on speed of material flow.

### Wet Separators

Suitable for wide range of particle size.

Extraordinary recovery of values in fine particles; sometimes better at 200 than at 50 mesh.

Generally used only on iron and magnetite recovery.

Water-handling cost involved, inasmuch as separation is generally on 20 per cent solids basis. Danger of freezing in winter.

### Dry Separators

Surprising results attained in separation of seemingly non-magnetic materials.

Adaptable to flow sheets using also other mechanical separations such as electrostatic separators or concentrating tables.

Units simple in design; can be set accurately for any given separation; automatic in operation and require no supervision.

Tests required to determine suitability for magnetic separation, even though similar materials can be separated.

Separations limited to particles larger than 150 mesh on account of air friction.

Fairly low output per unit in comparison with other types of mechanical separation.

Operation on 24-hour basis needed for low operating cost on account of comparatively low output per unit.

Material requires drying, crushing and screening to size for best results.

---

---

**Balance Sheet for  
ELECTROSTATIC SEPARATION**

---

---

**ASSETS**

Useful for separations not possible by other conventional means.

Useful for separations with hitherto unconsidered materials such as seeds, etc.

Low power consumption.

Particular ability to separate quartz and flint from mechanical mixtures.

**LIABILITIES**

More expensive than other types of separation.

Close sizing, absolute dryness and pre-determined temperature of material needed for best results.

Operator must be trained in use of high voltage.

Little is known of theory, resulting in machines that are sometimes "temperamental."

---

---

movals. For wet separation must be credited the large tonnages possible, and the splendid extraction of values that can be made with correspondingly low tailings losses. On the liability side for wet separation must be noted the danger of freezing in cold weather.

The dry magnetic machine, on the other hand, makes possible some remarkable separations of materials which do not appear to be magnetic. There

may well be products now being discarded which, with a modest expenditure for experiment and research, could be profitably recovered magnetically.

**Electrostatic Separation**

Electrostatic separation of non-metals may be of value in conjunction with other types of separation which have yielded a mixture of concentrates and

gangue that is no longer amenable to the separating force employed. Sometimes it may be used when other methods will not suffice. For instance, in the treatment of feldspar and kyanite, such materials may be treated magnetically by gravitational means with the production of a concentrate which will probably show a combination of the desired mineral with free silica or quartz. Electrostatic separation will divide this combination satisfactorily.

Many other interesting separations may be so effected, but the use of the method is considerably more expensive than most other types of mechanical separation on account of the low capacity of electrostatic separators per dollar of investment and operating cost.

There is a great field for further study into the various types of electrostatic separation. It is a surprising fact that scientists have not yet been able to determine which of the several types of electrostatic separation is being employed in a given instance. For example, they have not been able to discover whether a given separation is being brought about by a difference in dielectric constant, or by differences in surface conductivity or some of the pyroelectric effects.

## FLOCCULATION AND DEFLOCCULATION

**By GEORGE M. DARBY**

*The Dorr Co., New York, N. Y.*

**I**N SPITE OF the tremendous amount of work which has been done in the field of colloids, only a limited amount of it is of practical or theoretical use. Due to the presence of uncontrolled variables, a lot of work is contradictory. However, certain useful principles have stood the test of time and are applicable in a great many instances. In certain cases, the mixtures encountered are so complex that no theory can be applied and the method of "try everything on the shelf" must be used.

If flocculation cannot be accomplished by electrolyte or colloid addition, the formation in the solution of a very fluffy or gelatinous precipitate which carries down the colloidal or semi-colloidal material with it often works. This is undoubtedly the most commonly used method. In spite of its very extensive use in water purification, the method is by no means perfected and studies on iron and alum floc formation are appearing every little while.

In the last few years a certain type of mechanical flocculator has been successfully used to aid infloc formation and to

make a given amount of floc do more work, thereby reducing chemical consumption.

In certain cases it is not only desirable to render a suspension flocculent so as to make it settle but it is also de-

sirable to make the flocs very compact, thus reducing the volume of the settled sludge. This subject has received very little study and more is certainly desirable.

Many good chemical deflocculants are known and new ones are appearing constantly, especially organic ones. Temporary deflocculation may also be accomplished by mechanical means.

The effect of temperature on flocculation is very marked and probably deserves a good deal more study than it has already had.

---

---

**Balance Sheet for  
FLOCCULATING AND DEFLOCCULATING**

---

---

**ASSETS**

Tremendous amount of theoretical work has been done and certain useful principles are well established.

Floc formation is being actively studied both experimentally and practically.

Machines are available to aid floc formation and reduce chemical consumption.

---

---

**LIABILITIES**

Much data in literature is conflicting due to uncontrolled variables.

"Try - Everything - on - the - Shelf" method must often be used.

More data on shrinking of flocs desirable.

More detailed presentation of practical results is desirable.

---

---

# CENTRIFUGAL SEPARATION

By A. E. FLOWERS

*De Laval Separator Co.  
Poughkeepsie, N. Y.*

IN SPITE of the great possibilities of separating and filtering by centrifuges these operations are but little known and used. The most common exceptions are the so-called basket centrifugals for recovery of crystals and precipitates in chemical plants and sugar refineries, and the limited use of centrifugal separators for such uses as the dewaxing of bright stock in oil refineries, yeast making, and varnish clarification. A deceptively simple appearing balance sheet might be prepared on this basis, but, as will appear, the simplicity would be only apparent.

It is rather interesting to note the widespread knowledge of the use of the basket centrifuge as a "dryer" in laundries, dry-cleaning establishments, and in chemical plants, sugar refineries, and the like, for removing excess liquids from clothes, crystals, and for filtering and washing operations. Few, if any, new chemical processes are put into operation in which the possible applications of basket centrifuges are not given thorough consideration, usually to the extent of preparing a process flowsheet with initial installation costs and subsequent operating costs, predetermined by calculation and balanced against the operating savings and advantages derived from higher quality of product.

There is also a fairly general appreciation of the special advantages of centrifugal basket filters over plate-and-frame and vacuum-rotary or bag filters, in their more complete removal of mother and wash liquors and the ease of washing crystals, factors which enhance yield, purity, and dryness of product. In many processes these advantages are sufficient to render unimportant the somewhat greater cost of labor, attention, repair, and upkeep.

The centrifugal cream separator is so universally used that practically everyone knows about it. This general knowledge leads many enterprising operators to reconsider those stages of their processes where separations are being made by established methods, to determine whether centrifugal machines might be applicable and useful. Sometimes a too energetic person will make tests with an old cream separator. This is inadvisable and seldom leads to any useful results, because the internal construction of the cream separator is not adapted to the separation of varying

proportions of immiscible liquids, but only to a ratio concentration of an emulsion suspended or dispersed in a serum.

The makers of centrifugal machines have accumulated much experience from the use of their machines in a variety of processes. In addition, their development staffs have a large fund of data and experience in adapting their machines to proposed applications, as well as detailed information on the characteristics and peculiarities of the physical and chemical properties that control centrifugal separability of process materials. This information is not only derived from processes in actual operation, but also from a vast number of tests. Their data therefore do not only cover the cases that are commercially successful, but also those that are technically workable, whether economically feasible or not, as well as those that are not technically possible. These data on technically non-workable separations are an important asset in the consideration of any new applications.

Although some knowledge about the possibility of liquid-liquid separations exists, the application of high-speed centrifuges is too often dismissed as

---

---

## Balance Sheet for CENTRIFUGAL SEPARATION

### ASSETS

General acquaintance with advantages of basket centrifugals for collecting crystals and for removing liquids from solids.

General appreciation of merits of centrifugal basket filters where complete removal of mother liquor and washing of solids is desirable.

General knowledge of centrifugal cream separator.

Some information on usefulness of high-speed continuous liquid-liquid separators.

Manufacturers' and users' knowledge of the characteristics of centrifugal machines.

### LIABILITIES

Almost complete absence of published research work on theory and characteristics of centrifugal separators.

Absence of information on general physical and chemical characteristics required for centrifugal separation, and of published data on particular materials or on processes actually in operation.

Dearth of published data on actual applications and operations of centrifugal machines.

General lack of appreciation of possible applications of high speed continuous liquid-liquid separators.

"not feasible in our case," or it may not even be considered at all. When adaptable, and given an adequate trial, it becomes firmly established due to the small floor space needed, the high throughput possible, and the shortening of the process time, which reduces the quantities in process and makes it relatively easy to stop, start, change over to another batch, and adapt production to demand.

Users of centrifugal separators, such as oil refiners for bright stock, yeast makers for concentrating yeast, varnish manufacturers for clarifying varnish, wineries for clarifying fine wines, power plants for purifying lubricating oil, electrical operating companies for removing water and sediment from insulating oil, woolen mills for separating grease from wool washings, and latex users for concentration of rubber solids, have gained an extensive operating experience. When consulted they have been very generous in releasing this experience for the benefit of others. There is a vast potential field of usefulness for the centrifugal liquid-liquid separator and wherever such separations are now being accomplished by



other means the process supervisors would profit by consulting other users and take advantage of their experience.

On the debit side of the balance sheet must appear, first and foremost, an almost complete absence of any published research work on the theory and characteristics of centrifugal separators. Even less information has been presented on the separability characteristics of materials. The first lack is easy to understand, as this function may seem to be primarily the duty (or privilege) of the machine manufacturers. The latter, however, falls quite properly within the province of research workers in universities and endowed research institutions. It is hopefully commended to their attention.

There is also a dearth of published data on actual operating results of centrifugal installations. As pointed out, the supervisors of such processes are quite generous in giving helpful information, when requested, but are apparently too busy and intent upon their own affairs to submit their data for publication. It has been difficult, even for the manufacturers, to get data on labor and repair costs, in definite relation to operating hours, to output of processed material, or even on an annual basis. Such information would be of great value to all in the profession and its divulgence should not, it would seem, betray any trade secrets.

Information on rusting and corrosion of parts is also scarce and difficult to get, but is important as a supplement to, and for coordination with, laboratory tests for corrosion resistance, since many factors which enter into plant operation are not directly measurable or duplicable on a laboratory scale. These points are prayerfully commended to the users of centrifugal machines in the hope that they may contribute their share of information from experience. The makers of centrifugal equipment have been zealous in giving service and in investigating and correcting every known case of difficulty or trouble, and are continually improving their equipment in the light of that experience. It would be even better to be able to anticipate some of these difficulties, and prevent them.

There is still a lack of appreciation, on the part of the supervisors of present processes, of the many possible applications of continuous liquid-liquid separators. The number of industries is so great and the variety of processes so immense that it is physically impossible to survey them in any but the most cursory manner. In many cases the actual steps in the process are also unknown outside the plants where they are used. Often the processes are, properly, trade secrets. It is impossible, therefore, to reach into this field directly or to know where to look to

find the plants, the processes, or the people in charge, in order to bring to their attention the possible application of centrifugal separators. In many ways this item may be considered the largest

single liability. It is hoped that this article may in some measure help to pierce the blank wall and so contribute to further improvement in this unit operation step.

## HIGH PRESSURE TECHNIQUE

By NORMAN W. KRASE

*University of Illinois  
Urbana, Ill.*

**A**LTHOUGH high pressure technique is a specialized field involving many elements of unique importance, nevertheless the chemical engineering applications cut across many other well established unit operations. For example: fluid flow, heat transfer, distillation, fractional condensation. To the extent that these unit operations are undeveloped, so high pressure application is likewise undeveloped.

The requirements of this field are legion. Ultimately physical and chemical measurements will have to be extended to at least 300 atm. to permit intelligent and profitable application of elevated pressures. The immediate and urgent need in this field is (a) correlation and critical analysis of the existing data on physical properties of pure and mixed systems and (b) extension of

measurements of these properties—particularly P-V-T data on mixed gases, gas solubility and liquid-vapor equilibria, viscosity and other properties of importance in fluid flow and heat transfer design problems. While many other phases of this technology are in an unsatisfactory state of development, a filling-in of gaps in existing data would help in guiding future effort.

No other single chemical engineering development in the past decade has been so stimulating to the imagination and constructive thinking of scientists and engineers. Considering the scarcity of fundamental measurements progress has been amazingly rapid. This field has suffered disproportionately during the depression because only organizations of considerable resources could carry on in this line of development.

---

---

### Balance Sheet for HIGH PRESSURE TECHNIQUE

#### ASSETS

Developments have stimulated thought and given impetus—particularly to organic chemistry.

Many important compounds synthesized and replacing natural products because of lower cost and greater purity.

Successful safety record of plants draws favorable attention.

Technique gradually becoming standardized.

Suitable equipment available from variety of manufacturers.

Basic equipment design factors gradually coming to light.

#### LIABILITIES

Fundamental data on physical properties very incomplete.

Usual physical chemical laws not applicable without considerable modification.

Comparatively few productive workers contributing to knowledge in this field.

New developments frequently demand modification of technique.

High pressure equipment has as disadvantages:

- (a) Special equipment necessitates large investment.
  - (b) Obsolescence, depreciation and maintenance are high.
  - (c) Skilled operators are essential.
  - (d) Automatic instrumentation is difficult.
- 
- 
-

# UNIT PROCESSES IN ORGANIC SYNTHESIS

Edited by P. H. GROGGINS

Senior Chemist, Color and Farm Waste  
Division, Bureau of Chemistry and Soils  
U. S. Department of Agriculture  
Washington, D. C.

**D**URING the past half century the activity of workers in the field of organic synthesis has swollen to unwieldy proportions our store of information about new products. As a result, most organic chemists have been constrained to focus their interest on some restricted field. Beyond his immediate professional problems, the chemist is generally not so much interested in the countless new carbon compounds that are synthesized as he is in the reaction mechanism and technique employed. To derive the fullest benefit from the accumulated knowledge and current contributions, it is obviously advantageous to record the development of organic synthesis in terms of the comparatively few underlying unit processes.

Although the following list is incomplete, it is believed that the unit processes listed below will account for most of the technical operations involving organic synthesis.

1. Nitration
2. Amination by reduction
3. Diazotization
4. Halogenation
5. Sulphonation
6. Amination by ammonolysis
7. Oxidation
8. Hydrogenation
9. Alkylation
10. Esterification
11. Hydrolysis
12. Friedel and Crafts reaction
13. Polymerization

Other well-defined processes which have a limited technical application are nitrosation, the Grignard, the Skraup, and the Scotten-Bauman reactions.

In commercial operations involving organic synthesis it is necessary to bring to the application of such reactions the pertinent information derived from inorganic and physical chemistry, as well as the contributions of the chemical engineer. Hence, in any comprehensive study of this subject, considera-

tion should be given not only to the chemistry and products of reaction but equally to other contributing factors and agencies which lead to efficient operation. The term "unit process" is used by Groggins ("unit process in Organic Synthesis," Chemical Engineering Series, McGraw-Hill Book Co.; now in press) to represent the embodiment of all the factors in the technical application of an individual reaction in organic synthesis.

The desirability or necessity of employing such a concise and descriptive term can be appreciated readily from the following illustration: In the process of synthesizing dimethylaniline from benzene, the following three distinct unit processes may be involved: Nitration, amination by reduction, and alkylation. To obtain the best results in this or similar synthetical operations, it is undoubtedly necessary to know the fundamentals of each of the unit processes involved, as well as the principles of the accompanying unit operations.

Unit processes deal principally with chemical reactions, whereas unit operations relate largely to physical phenomena. The former are based on changes in chemical constitution or molecular structure, while the latter involve changes of state or position. Unit processes bring about distinctive chemical transformations in the materials treated, these changes being conditioned largely by the intrinsic properties of the reactants. On the other hand, the factors affecting physical movements or changes, i.e., the underlying principles of unit operations, may in many instances be discussed apart from the chemical nature of the materials handled. Unit processes and unit operations have, however, an important inter-relationship. (See article by T. R. Olive elsewhere in this issue.)

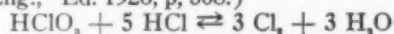
Experience has demonstrated that a

study leading to the formulation of a philosophy of each unit process should include the following related phases: (1) An examination of the reactants; (2) An investigation of the mechanism and dynamics of the reaction; (3) A knowledge of the chemical and physical factors involved; (4) Observations regarding the design, construction, and operating control of equipment; (5) Illustrative technical applications embodying remarks regarding the control of operations.

A re-examination of the physical and chemical properties of the reactants will probably be a fruitful activity for organic chemists. Within recent years the physicist and the physical chemist have introduced new concepts regarding the structure and behavior of atoms and molecules. With the advent of new and more accurate tools the border line of our knowledge has been pushed back and a new horizon can now be envisioned. Valuable information regarding spectroscopic, vapor pressure, and conductivity measurements, as well as free and activation energy calculations have been made available. Very little of this new information has found its way into texts dealing with organic synthesis. Clearly, such a correlation is desirable.

In certain unit processes a study of the inorganic reactants has led to marked progress. For example, in amination by ammonolysis it has been shown that ammonia ( $\text{NH}_3$ ) and not ammonium hydroxide is the aminating agent. (Groggins and Stirton, *Ind. Eng. Chem.*, Vol. 25, 1932, pp. 169 and 274.) It has been found that with increasing temperature, the capacity of  $\text{NH}_3$  to combine with  $\text{H}_2\text{O}$  to form the ionogen  $\text{NH}_4\text{OH}$  gradually diminishes. When ammonium salts are introduced the decrease in pH is more rapid. When aromatic halogen compounds are treated with aqueous ammonia, the concen-

tration of the hydrogen halide or arylammonium halide determines the equilibrium of the reaction for each temperature. These considerations have led to the belief that the reaction mass might possibly become acidic and thus account for the formation of secondary amines and the attack on iron autoclaves and the reduction of anthraquinone amines. The use of oxyhalogen compounds to oxidize the hydrogen halide split off in the ammonolysis of halogenoanthraquinones has proved to be eminently successful, presumably because such oxidants are inert except in the presence of a strong acid. The oxidation of halogen hydracids by the oxyacids goes almost completely to the right in acid solutions, but in alkaline solutions the reaction is largely reversed owing to the removal of hydrogen ions. (Ephraim, "Inorganic Chem. Eng.," Ed. 1926, p. 308.)



In sulphonation, the postulate that the true sulphonating agent is not  $\text{H}_2\text{SO}_4$ , but rather  $\text{SO}_3$  bound loosely to an organic compound, or water, as in pyrosulphuric acid,  $\text{SO}_3 - \text{H}_2\text{O} - \text{SO}_3$ , has led to interesting and fruitful research. It is almost certain that  $\text{SO}_3$ , introduced either as a liquid or vapor into a suitable "cycle system" will play a more important rôle in future technical sulphonations.

In nitrations a similar situation exists, for it is generally known that weak nitric acid which is dissociated into  $\text{H}$  and  $\text{NO}_3$  ions is not a satisfactory nitrating agent. Only when this compound is present in the ester form,  $\text{O}_2\text{N.OH}$ , or the anhydride form,  $\text{O}_2\text{N} - \text{O} - \text{O}_2\text{N}$ , can good results be obtained.

It appears that emphasis should be given to the fact that the study of carbon compounds under the historical name of organic chemistry is not a mere coincidence. It should be recognized that the ancestry of the reactants and the environment of the reaction play comparable rôles in the realm of organic synthesis and in the world of living things. The time of physical and chemical activity, the temperature and humidity, and the concentration of beneficial or deleterious gases are only a few of the factors which influence both synthetical reactions and living organisms.

Most reactions in organic chemistry are distinctly sensitive to changes in physical and chemical conditions. In works practice accurate knowledge regarding these factors can often be translated into profits. Heretofore investigations in this field have to a large extent been empirical, but with increasing knowledge of the mechanism and dynamics of the reaction preliminary calculations will probably to a consid-

erable extent obviate exploratory experimentation.

**Design and Construction of Equipment.** It should be apparent that no sound judgment can be made in this field until a thorough study of the other aspects of a unit process have been made. It is obviously necessary, (1) to examine the properties of the reactants, (2) to study the reaction mechanism and equilibrium conditions, and (3) to know the influence of the numerous related factors which govern both the quantity and quality of the desired product.

Within recent years many new materials of construction have been made available for carrying out operations at high pressures or with corrosive materials. The advent of such resistant materials has beneficially affected a number of unit processes. Continuous operations at high pressures have become standard procedure, thereby paving the way for new and more economical synthetical methods.

In the past, civil and mechanical engineers have deplored the fact that there was no unanimity of opinion among chemical engineers regarding the details of any proposed construction. The reasons for such a situation are clear when consideration is given to the rapid advances in chemical technology, the circumscribed experience of the industrial chemist, the limited number of satisfactory materials of construction, and the inadequate physical and chemical data for all phases of the reaction.

Any general discussion regarding the design and construction of equipment must obviously be restricted to types suitable for the manufacture of widely used products. In any unit process, modifications in the design and construction of equipment must be made for the treatment of gases, liquids, or solids; for batch or continuous operations, and for the isolation of the finished product in a suitable form. In plant practice the final design is ordinarily the result of the views of many minds on many points, and in such deliberations the views of management and sales are not ignored.

In general it is possible and often

profitable to discuss certain broad principles underlying the design, construction and control of equipment. When correlated with other aspects of a unit process such a discussion may prove to be of interest to those skilled in the art, and indispensable to the uninitiated who have not yet had the opportunity to inspect and operate such systems.

An examination of the literature relating to any unit process in organic synthesis reveals that there may be many related means to the same end. The desirability of codifying the underlying principles and factors has long been recognized. It is clear that the satisfactory interpretation of any unit process depends on discovering the common among the apparently diverse reactions. It is often enlightening also to explore the common bonds which characterize a number of the unit processes. When the broad principles are understood, the relationships of individual phenomena are recognized, and the analysis and solution of problems are simplified.

What appears to be common to most of the widely accepted explanations regarding the mechanism of a reaction are the following points: (1) The formation of ionized addition complexes because of auxiliary valence in the reacting molecules. Such addition compounds are generally colored and are characterized by conductivity. The presence of certain key atoms such as  $\text{Cl}$ ,  $\text{O}$ ,  $\text{S}$ ,  $\text{N}$ , and  $\text{C}=\text{C}$  which possess a high atomic energy (total available energy minus the latent or bond energy) appear to be necessary for the initiation of the reaction. (Prins, *Rec. trav. chim.*, Vol. 44, 1925, p. 166.) (2) Rearrangement of the unstable addition complex to one involving principal valences. (3) Stabilization; the dissociation of the complex into relatively stable compounds.

The fact that stable stoichiometric addition products are not isolable in many of the unit processes does not preclude their existence in the course of the reaction. It should be remembered that stable easily isolated addition compounds do not possess catalytic character, and the instability that makes

Table I. Relationships in Some Unit Processes of Organic Synthesis

Unit Process	Reactants	Products Formed	Acid Split Off
Nitration.....	$\text{R.H} + \text{O}_2\text{N.O.OCC}_6\text{H}_5$	$\text{R.NO}_2$	$\text{CH}_3\text{COOH}$
Nitration.....	$\text{R.H} + \text{O}_2\text{N.O.OCC}_6\text{H}_5$	$\text{R.NO}_2$	$\text{C}_6\text{H}_5\text{COOH}$
Nitration.....	$\text{R.H} + \text{O}_2\text{N.O.NO}_2$	$\text{R.NO}_2$	$\text{HNO}_3$
Nitration.....	$\text{R.OH} + \text{O}_2\text{N.NO}_2$	$\text{R.NO}_2$	
Friedel and Crafts.....	$\text{R.H} + \text{CH}_3\text{CO.Cl}$	$\text{R.COCH}_3$	$\text{HCl}$
Friedel and Crafts.....	$\text{R.H} + \text{C}_6\text{H}_5\text{CO.Cl}$	$\text{R.COC}_6\text{H}_5$	$\text{HCl}$
Friedel and Crafts.....	$\text{R.H} + \text{CH}_3\text{CO} - \text{O} - \text{CH}_3\text{CO}$	$\text{R.COCH}_3$	$\text{HCl}$
Sulphonation.....	$\text{R.H} + \text{SO}_3$	$\text{R.SO}_3\text{H}$	
Sulphonation.....	$\text{R.H} + \text{C}_6\text{H}_5\text{N.SO}_3$	$\text{R.SO}_3\text{H}$	
Sulphonation.....	$\text{R.H} + \text{H}_2\text{O} = (\text{SO}_3)_2$	$\text{R.SO}_3\text{H}$	$\text{H}_2\text{SO}_4$
Sulphonation.....	$\text{R.OH} + \text{HO} - \text{SO}_3 - \text{Cl}$	$\text{OH} - \text{R} - \text{SO}_3\text{H}$	$\text{HCl}$
Halogenation.....	$\text{R.OH} + \text{Cl}_2 = \text{S} = \text{O}$	$\text{R.Cl}$	$\text{SO}_2 + \text{HCl}$
Halogenation.....	$\text{R.SO}_3\text{H} + \text{Cl}_2 = \text{S} = \text{O}$	$\text{R.Cl}$	$\text{SO}_2 + \text{HCl}$



isolation difficult constitutes the precise attributes for catalytic effectiveness of the intermediate compound. An intermediate, particularly when it exists in equilibrium in a very limited concentration, may fully determine the course of the reaction through its decomposition, for it is the most unstable component of the equilibrium. (Wohl and Wertyporoch, *Ber.*, Vol. 64, 1931, p. 1357; Maxted, *Chem. and Ind.*, Vol. 149, 1931.)

The preceding generalities may be illustrated by the following analogy drawn from the field of nitration: When a highly nitrated product, such as picric acid, unites with a hydrocarbon possessing special additive capacity, e.g., naphthalene, the product formed is stable. Similar forces are involved in the primary coupling of nitric acid anhydride, as is evidenced by the formation of the colored addition product. Here, however, the equilibrium is far on the side of dissociation, and the addition product which is present only in small quantities cannot be isolated without decomposition, the nitration process depending on its successive decomposition and reformation.

The inter and intra-relationships in some unit processes as set forth in Table I should lead to fruitful speculation. In most cases the reagent may be considered as a simple or mixed anhydride. Upon completion of the reaction, part of the anhydride is found linked to the organic compound and part is generally combined with a hydrogen atom from the organic compound as free acid.

The preceding information serves to throw light on the nature of the active components as well as the mechanism of the reaction. In the Friedel and Crafts synthesis the liberation of hydrogen chloride plays an important part in the progress of the reaction, yet, the acid anhydride contains no halogen initially. By analogy it would appear reasonable to postulate the intermediate formation of an acid chloride because of the action of anhydrous aluminum chloride. When acetic anhydride was thus treated, it was found that the volatile acetyl chloride could be distilled off and the residual non-volatile aluminum chloride salt of acetic acid could be made to react according to the Friedel and Crafts reaction.

From an examination of the nitrating agents in Table I it may be presumed that an oxonium compound,  $O_2N = O = HR$ , is formed as an addition complex during the reaction. Other reasonable postulations are (1) that nitric or other related anhydrides are the true nitrating agents, (2) the  $N_2O_5$  could be employed in the nitration of compounds containing hydroxyl groups, the preliminary action being simple addition,  $O_2N = O = HR$ ;

and (3) that the successful application of  $N_2O_5$  in the nitration of hydrocarbons could probably be realized only under conditions which make possible the formation of an oxonium compound or a similar unstable addition complex. In this connection it is of interest to note that nitrogen tetroxide can be employed in the esterification of carbohydrates (U. S. Patent No. 1,917,400), and that  $N_2O_5$  can serve as a nitrating agent in the presence of oxygen (U. S. P. 1,723,761), concentrated sulphuric acid, and of aluminum chloride (Schaarschmidt, *Ber.*, Vol. 57B, 1924, p. 2065).

Table I is merely an outline of the inter and intra-relationships of some unit processes. Even thus, it is a use-

ful guide for predicting some characteristics of reactions in organic chemistry. When more data are made available regarding the free energy of the reacting components and the conductivity of the addition complexes such a chart may be of great service in the study of unit processes.

In the following paragraphs there is presented a very brief summary of the "ASSETS AND LIABILITIES" of some unit processes. It will be seen that great strides have been made but much remains to be done. It appears reasonable to believe that a correlation of the important factors in unit processes will do much to hasten future progress in the field.

## NITRATION

By P. H. GROGGINS

The employment of cycle acid, the introduction of internal cooling coils, and the advent of the Hough nitrator were largely responsible for the development of large and safe operating units. For obvious reasons this unit process receives a fluctuating amount of attention, but the breadth and intensity of work during periods involving national defense have brought such operations to a comparatively high state of perfection. New developments involve the broader use of nitrogen tetroxide.

Examination of the formulations for nitrating agents leads to the following generalizations. The nitrating agents are complexes which:

- (1) Contain the  $NO_2$  group as part of a labile complex.
- (2) Are similar in structure to nitric acid esters or anhydrides and generally the  $NO_2$  group is held by a shared  $O_2$ .

(3) These compounds possess pronounced unsaturation, thus facilitating addition.

(4) On stabilization after nitration an acid is split off, and the latter may very probably participate in a second reaction.

The comparative reactivity of such simple or mixed nitric acid anhydrides has not been evaluated quantitatively. Such information would frequently be useful in determining the choice of the nitrating agent and the conditions of reaction.

Operating technique for principal nitro compounds is highly standardized. Recent patents relate largely to preparation of nitrocelluloses having specific properties.

Exploration of mixed, nitric acid anhydrides comprising nitric with acetic or propionic acids may prove instructive.

Explosive properties of highly nitrated compounds have been correlated with their heats of formation.

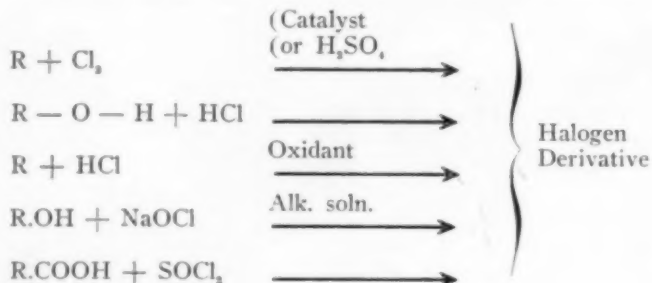
## HALOGENATION

By P. H. GROGGINS  
and H. P. NEWTON

The halogenation of organic compounds is carried out on a large scale, but the chloro derivatives are by far the most important, because of the

greater economy in effecting their preparation. The bromine and iodine derivatives, however, sometimes have certain advantages due to the ease in effecting their replacement in subsequent reactions.

Examination of some chlorinations indicates that the presence of a metal catalyst or of an oxygen containing compound accelerates the reaction.



### Balance Sheet for NITRATION

#### ASSETS

Nitration believed to be caused by activity of simple or mixed nitric acid anhydrides.

Mechanism of reaction extensively studied, but evidence for addition not conclusively established.

Reactions with mixed nitric acid anhydrides, e.g., acetyl nitrate have contributed to our knowledge of mechanism of reaction.

Thermal factors and data comprehensively studied.

Use of "cycle acid" technique better developed than in other unit processes.

Chemical and physical factors largely established.

Control to insure safety in operation highly developed.

Apparatus for batch operations largely standardized.

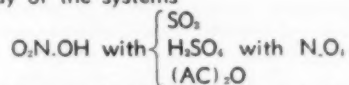
#### LIABILITIES

Studies on the preparation and comparative activity of nitric acid anhydrides desirable.

Further work on the formation or detection of addition compounds would be instructive.

Mechanical and solubility losses are still appreciable.

Study of the systems



should be undertaken with new tools as a problem in manufacture of esters of carbohydrates.

Although this unit process has received more technical attention than any other, continuous large scale processes are far from perfect.

Expansion in nitration operations awaits development in use of  $\text{N}_2\text{O}_5$ .

### Balance Sheet for HALOGENATION

#### ASSETS

Recent information on activation energy of halogens sheds new light on many phases of halogenation process.

Chemical and physical properties of halogens and halides correlated with a number of halogenations.

Certain intra-relationships of halogenating agents developed.

Function of mixed halogens, e.g., Br, Cl, as well as halogen compounds existing in two states of oxidation becoming appreciated.

Vapor phase, non-catalytic halogenations of paraffin hydrocarbons increasing.

Many continuous halogenation processes developed.

Use of comparatively inert gases and solvents being extended.

New tools make satisfactory physical control of both liquid and vapor phase processes possible.

#### LIABILITIES

Thermodynamic studies of many halogenations are only partially complete.

Equilibrium data relating to formation of mono and dihalogeno derivatives inadequate.

Only fragmentary correlation of halogenating agents made.

Control of reaction often largely empirical, being dependent on time of contact, temperature, ratio of halogenating agent, type of catalyst, or any combination of these factors.

Very little published on chemical and physical factors affecting halogenations.

Materials of construction limited, because of inability to withstand corrosive action of hydrogen halides either in presence or absence of  $\text{H}_2\text{O}$ .

In vapor phase processes difficulties are encountered in limiting the products to those desired.

Violence of vapor phase halogenations necessitates expedients to moderate and control the reaction.

Reactions of addition, substitution, and replacement are possible, and the optimum conditions vary with the particular halogen and the nature of the agent.

A wide variety of agents is available, and their use is governed by economic factors in producing specific compounds.

Halogenation in the chain and ring of alkaryl compounds has been correlated with specific catalysts, but exclusion of undesired compounds is not obtained in practice.

Many ingenious methods have been devised to control the rate and intensity of vapor phase reactions. Although these expedients are factors in the cost of production, they do make possible the carrying out of large scale operations with safety.

In the past, materials of construction were drastically limited because of the corrosive character of the halogen hydracids. Advances in the fabrication of lead or alloy lined equipment have to some extent solved this problem. Because of the wide variations in the physical and chemical properties of the various halogen derivatives, and the diversity of halogenation agents, no generalization can be drawn regarding the design and construction of equipment.

The past decade has witnessed a great development in the manufacture of fluoro salts for refrigerants and dyes.

## SULPHONATION

By W. A. SIMPSON

During the past twenty years our knowledge of the chemistry of sulphonation has increased and a great deal of progress has been made in the technical application of this unit process. In many cases, where it was formerly necessary to use large excesses of sulphuric acid, economies have been made by applying new principles and methods. Catalysts, especially mercury, have become more and more important. Various physical factors, too, have been brought into play. Reduced pressure, high pressure, presence of an inert solvent, and vapor phase operations now play an important rôle in technical sulphonations.

New applications of sulphonated products, notably the sulphonated oils and other aliphatic compounds, have opened up an ever expanding field in sulphonation work. Valuable detergents, wetting and emulsifying agents have thus been produced.

In designing apparatus for sulphonation work, a complete knowledge of the physical characteristics of the materials to be used is essential as well as a thorough understanding of the underlying principles and theory of the sul-

phonation reaction. Where isomeric sulphonic acids are produced, it is essential to know not only the exact conditions necessary to produce the desired product in the largest possible amount, but also the most effective means of their separation.

While sulphuric acid is undoubtedly the most common sulphonating agent, acid sulphates, sulphites and chlorosulphonic acid are extensively used. Sulphur trioxide and its addition compounds, and sulphur dioxide have also been added to the list.

Many refinements in both batch and continuous processes have recently been introduced. In many respects, however, the control of the operation is largely empirical, being based on experience rather than physico-chemical devices.

## AMINATION BY REDUCTION

By P. H. GROGGINS

Because of the importance of amino compounds to the dye industry, amination by reduction has been widely and intensively studied.

Generally, high operating efficiencies are obtained in the preparation of the important primary amines.

The work of Prins (Series of five articles: *Chem. des Pays Bas.*, Vol. 42, 1923, to Vol. 44, 1925) on the mechanism of the reaction in acid systems, and that of Brand and his coworkers (*J. fur Prakt. Chem.*, Vol. 120, 1928, p. 160; Vol. 131, 1931, p. 119; Vol. 133, 1932, p. 355) in neutral and alkaline media are of particular interest.

Although the physical and chemical properties of iron turnings are recognized as being important, the purchase of this material is frequently greatly influenced by other factors such as location and price.

The intra-relationships of various reducing systems are now being recognized. This may lead to modifications of operating technique for liquid phase reductions.

In the design and construction of equipment, insufficient attention has been given to the facts (1) that the nitro compound and water generally have only a limited miscibility or solubility, (2) that the aqueous portion holds the catalyst in solution, and (3) the reaction is polymolecular and requires an intimate mixture of all the components.

The influence of organic solvents in carrying out reductions should be further explored, since it may throw light on the mechanism of reaction, formation of addition compounds and the inter-relationship with other unit processes. (Kiewiet & Stephen, *J. Chem. Soc.*, 1931; 82.)

---

---

### Balance Sheet for SULPHONATION

#### ASSETS

Information concerning mono and disulphonation of unsubstituted hydrocarbons very extensive and complete.

Data about anthraquinone sulphonation complete enough so that guesswork has been eliminated.

Data concerning sulphonation by sulphites constantly growing, so that a whole series of new sulphonic acids has been made available.

Continuous process for sulphonation of unsubstituted hydrocarbons well established.

Catalysts, especially mercury, have been successfully used.

Modern methods of heating and control readily applicable to sulphonation.

Use of reduced pressure used advantageously in some cases.

Preparation of sulphonic acids from quinones by action of  $\text{SO}_2$  well developed.

Many successful methods available for separation of isomeric sulphonic acids.

#### LIABILITIES

Orientation of sulphuric acids as a function of  $\text{SO}_2$  concentration incomplete in many cases.

Further correlation of the percentage of an isomer in a mixture with melting points of the sulphon-chlorides desirable.

Continuous processes needed for sulphonation of substances other than hydrocarbons—phenols for instance.

Physical properties lacking in detail for many sulphonic acids and salts.

Most efficient separation methods for many isomeric sulphonic acids still to be published.

Improvement needed in sulphonation methods for many substances now using chlorosulphonic acid.

Extension of vapor phase sulphonation successfully to all volatile substances.

More data needed for solid sulphonations by sulphur trioxide, either gaseous or liquid, particularly in the presence of inert solvents.

---

---

### Balance Sheet for AMINATION BY REDUCTION

#### ASSETS

Mechanism of reaction widely studied and postulations regarding theory have been translated profitably to plant practice.

Reduction with iron considered a polymolecular reaction involving three components, acid, metal, and reducible substance.

Substitution of free acid by easily hydrolyzed salts has simplified plant practice in many operations.

Many chemical and physical factors explored but knowledge is fragmentary and needs correlation.

High operating efficiencies obtained in production of important primary amines.

Reduction of polynitro compounds in inert organic solvents is being explored.

Feasibility of using gaseous hydrogen under pressure in liquid phase catalytic reactions demonstrated. Expansion of use of gaseous hydrogen appears probable.

#### LIABILITIES

Quantitative data regarding comparative activity of various reducing systems lacking

Exploration of use of bimetallic systems to regulate rate and intensity of reduction desirable.

pH control of reductions lacking.

Efficiency of standard equipment has not been markedly improved; principal defect failure to recognize: (a) that reaction is polymolecular, (b) practical homogeneity desirable.

Continuous processes not yet developed, principally because of— (a) lack of equilibrium data, and (b) difficulties encountered in accompanying unit operations, e.g., filtration of reduction products.

The new and cheaper methods for the preparation of hydrogen suggests the advisability of re-examining vapor phase reactions with catalyst.



# AMINATION BY AMMONOLYSIS

By P. H. GROGGINS  
and A. J. STIRTON

Considerable expansion in activities involving amination by ammonolysis has occurred during the past few years.

The production of aniline, 2-aminoanthraquinone and the alkylamines is now being carried out on a large scale. The Dow Chemical Co. has contributed largely to the chemical engineering advances relating to the construction and control of pressure systems for continuous operations.

The mechanism of the reaction and the factors involved have been studied. Ammonolysis with aqueous ammonia is

best interpreted as being brought about by the activity of  $\text{NH}_3$  and not the base  $\text{NH}_4\text{OH}$ . Increased concentrations of  $\text{NH}_3$  favor the formation of purer primary amines.

The replacement of halogen atoms or the sulphonic acid group is best carried out in the presence of oxidants, and a metal following hydrogen in the electrochemical series may in certain instances be employed advantageously as a catalyst. For the conversion of hydroxy compounds and aldehydes to amines, the presence of a reducing agent and an active metal is beneficial.

A study of the equilibrium shows that a maximum concentration of primary amine is to be obtained when the concentration of the acid ( $\text{HCl}$  or  $\text{NH}_4\text{HSO}_4$ ) or water which is split out is reduced to a minimum. In the ammonolysis of halogeno compounds the importance of this problem is accentuated by the fact that the pH of aqueous ammonia decreases with rising temperature and more rapidly under such conditions when ammonium salts are introduced. Oxyhalogen compounds can be employed advantageously to oxidize the hydrogen chloride or ammonium bisulphite.

The introduction of ferro alloys which would not be so susceptible to attack by the components in the pressure system is desirable. Increased knowledge regarding methods of crystallizing out solid amines in a pure state from the reaction mass would be of considerable value.

---

---

## Balance Sheet for AMINATION BY AMMONOLYSIS

### ASSETS

Fundamentals of process fairly well established.

With aq.  $\text{NH}_3$  reaction takes place in liquid phase and  $\text{NH}_3$  is the reactant.

Use of oxidants and reducing compounds correlated with type of compound to be aminated.

Catalytic influence of metals preceding and following hydrogen in the electrochemical series correlated with type of compound aminated.

Continuous aminations practical where reactants and amine are gases or liquids.

Equipment for both liquid and vapor phase operations available, but successful operations depend on trained and experienced personnel.

### LIABILITIES

Final reaction product always contains traces of byproducts.

Liquid phase reactions yield hydroxy derivatives and secondary amines.

Vapor phase reactions yield primary, secondary, and tertiary amines.

Separation of impurities in solid amines difficult.

Deleterious influence of impurities is often magnified in use of product.

Ferrous alloys which are not attacked by reactants or reaction products desirable.

Factors in design of equipment for specific compounds require study.

Further inquiries into suitable non-aqueous inert solvents for  $\text{NH}_3$  needed.

Satisfactory procedures for treating compounds containing both OH and  $\text{SO}_3\text{H}$  groups not yet developed.

---

---

## Balance Sheet for OXIDATION

### ASSETS

Oxidation reactions long known and widely used.

Use of selected oxidizing agents in liquid phase processes well established in practice.

Control methods for vapor phase oxidation of aromatic hydrocarbons and oxygenated aliphatic compounds with atmospheric oxygen well developed.

Recent developments in pressure oxidation of aliphatic hydrocarbons with atmospheric oxygen point way to their utilization as chemical raw materials and indicate limitations.

Improvements in methods of oxidation of heavy petroleum fractions indicate possible new sources of high molecular weight acids, alcohols, etc.

### LIABILITIES

Great variety of results restrict generalizations.

Processes are empirical and information not freely disseminated.

Necessity for use of catalysts in such processes introduces a major variable.

Processes have not been developed which yield single product, and the usual product mixtures have restricted uses.

Difficulties encountered in limiting the products to those desired restrict progress.

Controversy regarding generalizations on kinetics and mechanism of oxidation still exists.

# OXIDATION

By L. F. MARCK

Oxidations of organic compounds accompanied by the formation of water, carbon oxides, or both, or by the introduction of oxygen in the molecule, or by the step-down of an oxidizing agent from an unstable state of high oxidation to a more stable state of lower oxidation, are exothermic and tend to completion. In practically all cases, means need not be provided to force the completion of reaction, and it is generally necessary to limit or restrict the reaction to prevent continued oxidation. In most cases, the reactions are irreversible and once the desired point of oxidation is passed cannot be forced backward to correct the error.

Useful processes do not result from these favorable conversions until satisfactory reaction rates are obtained. One of the principal problems, therefore, in the case of oxidation reactions is the induction and maintenance of satisfactory reaction rates. Methods in use have, therefore, been developed from the standpoint of limiting the extent of reaction to the degree desired and of

controlling the rate of reaction to a point commensurate with heat removal.

Oxidations are conducted in the liquid phase in cases where high molecular weight, complex, and more or less thermally unstable substances are dealt with. Temperatures are low or moderate, and the extent of oxidation may be controlled by limiting the duration of operation, regulating the temperature, and by limiting the quantity of oxidizing agent. Oxidation may occur through the action of some oxygen-rich oxidizing agent or through the action of molecular oxygen in the presence of a catalyst.

Vapor phase reactions are only applied effectively to readily volatile substances of sufficient thermal stability to resist dissociation at elevated temperatures. A further limitation exists in that the desired product must also be thermally stable and comparatively resistant to continued oxidation. Solid or vapor phase catalysts may be employed with atmospheric oxygen to produce the desired oxidation. Temperatures are generally high and must be maintained in a narrow range for proper catalyst functioning. Control is effected by limiting time of contact, temperature, proportion of oxygen, catalyst activity, or combinations of these.

Comparison of oxidizing agents on the basis of electromotive force tending to be generated when oxidizing agent solution and hydrogen are made poles of a cell furnishes a certain arbitrary classification but cannot serve as an adequate basis for predicting the action of the oxidizing agents on different organic compounds. In the final analysis empirical data must be obtained and compared.

Certain generalizations regarding the applicability of elements as catalysts for the reaction are possible but are, for the most part, limited to groups or positions in the periodic system. Furthermore, the practice of using mixtures of catalysts, based on empirical knowledge, makes generalization still more difficult. However, practice has established the usefulness of certain elements and combinations as bases for comparison.

## HYDROGENATION

By MERILL R. FENSKE

Hydrogenation processes have been increasing in size, variety, number and importance. They make possible the interconversion of solid and liquid materials, the conversion of stenches to aromas, and the production of valuable products from waste materials. Practically any type of unsaturation occurring in the various organic compounds can be reduced with hydrogen in the presence of catalysts, and in addition

### Balance Sheet for HYDROGENATION

#### ASSETS

Makes possible the conversion of materials of various types and classes into new or more valuable products. Has considerably broadened the field of industrial organic chemistry.

Adaptable to large scale continuous operation.

Hydrogen can be produced from a variety of materials.

Generalized physical-chemical principles best possible basis for successful results. Close correlation with similar reactions in organic chemistry.

A variety of materials are suitable catalysts, and the types of hydrogenation reactions can be well classified.

Catalysts have been developed which are quite resistant to poisoning thereby allowing a wider variety of materials to be processed.

Relatively safe to operate.

New alloy steels have made possible rapid development of large scale processes.

#### LIABILITIES

Side reactions complicate process as well as the separation of the desired products and frequently new uses have to be developed for the disposal of materials resulting from side reactions. Usually requires extensive development work for successful process.

Small units are expensive and small scale hydrogen production costly.

Cheaper hydrogen in moderate and large quantities needed.

Only meagre and insignificant equilibrium data available. Physical data for systems at high temperatures and pressures lacking.

Little information on the results of combining hydrogenation with other reactions to broaden its applications.

Catalytic processes in general need intensive study. No clear understanding of mechanism or kinetics of reactions. High pressures often required to aid catalyst effect reaction.

Recovery and reactivation of catalysts a separate and additional problem.

Incomplete understanding of the failure of metals due to hydrogen attack..

### Balance Sheet for ESTERIFICATION

#### ASSETS

Fundamentals well understood.

Esterification limits for all acids relatively high.

Primary and secondary alcohols usually easy to esterify.

Esterification completed by separation of the products.

Distillation is available for the separation of the products.

Azeotropic mixtures are useful for many separations.

An additional substance such as toluene may aid by forming a ternary.

Advances in distillation theory and practice immediately translated into lower costs.

#### LIABILITIES

Many particular cases in which application is difficult.

Esterification velocity for some acids is very slow.

Tertiary alcohols difficult.

Necessary separations are frequently difficult.

The required exactness of fractionation may be excessively costly.

Our knowledge of azeotropic mixtures not sufficiently complete and exact.

Data for possibly desirable ternaries are incomplete.

Better designs of columns and more skilled operation needed to cut costs.

hydrogen enters into a variety of other reactions and syntheses to simplify, shorten, and cheapen the process.

Catalysts are essential to most hydrogenation reactions. They not only must effect the rapid addition of hydrogen to the material, but they must also guide and direct the desired reactions, and effect a balancing and harmonizing of many factors so that just the correct overall result is attained. They must be able to operate on liquid, solid, and gaseous materials, and in addition must not be readily poisoned or rendered inactive.

Recent developments in metallurgy, and in the production of hydrogen have enabled rapid advances to be made so that on one hand hydrogenation processes may be relatively simple, at low pressures and on a small scale, and on the other hand the operations may involve the processing of large quantities of materials, at high temperatures and pressures, in a continuous manner. Hydrogenation has already been applied successfully in the preparation of food stuffs, fuels, pharmaceuticals, fertilizers, and to an ever increasing variety of new chemicals.

## ESTERIFICATION

By E. EMMET REID

About seventy years ago Bertholet proved the complete reversibility of esterification and made satisfactory measurements of the limits when various acids are esterified with different alcohols. He showed that esterification goes to completion when water, one of the products of the reaction, is removed. The catalytic speeding up of esterification was also early discovered, yet until recently, the preparation of esters remained clumsy and wasteful. There was little urge for perfecting esterification processes until the fast growing lacquer industry began to make demands for enormous quantities of esters. From then until now rapid advances have been made in practice; large-scale batch and continuous processes have been developed and many millions of pounds of esters of the highest purity are now being turned out.

Distillation is used in most cases for separating the ester and water, that are formed, from each other and from the starting materials. Advances in esterification have consequently been dependent on an increased knowledge of unit operations. One great discovery that has advanced esterification practice is the use of azeotropic mixtures to facilitate separations. As little heat is taken up or given up in esterification and as only small quantities of cheap catalysts are sufficient to effect the reaction, the cost of carrying out the process is chiefly the cost of the required distillations. Improvements in the design and operation of columns have been immediately translated into lower costs for manufacturing esters. Further improvements must come from that direction.

### Balance Sheet for THE FRIEDEL AND CRAFTS REACTION

#### ASSETS

Mechanism of the reaction fairly well understood.

- (a) Data being coordinated.
- (b) Hypotheses regarding addition complexes further confirmed.
- (c) Conductivity of such complexes being correlated with their activity.

Function of aluminum chloride shown to be manifold, e.g., catalytic, condensing, and disruptive.

Prejudice against materials of reaction and construction being dissipated. Chemical factors on some syntheses worked out.

Important factors relating to the design and construction of equipment for ketones, keto acids, and aldehydes established.

#### LIABILITIES

Conductivity measurements of more addition complexes desired. Practically no information available for vapor phase reactions.

Data on influence of hydrogen chloride on numerous syntheses and under pressure desirable.

Correlation of halogen carriers and halogen compounds with type of condensation needs to be extended.

Method of acid halide formation from anhydride requires further study.

Improvements in design and construction of equipment on basis of present knowledge can be made.

### Balance Sheet for POLYMERIZATION

#### ASSETS

Raw materials for polymerization processes are abundant and cheap.

Scientific research has led to the production of resins which are far superior to natural products.

In polymerization, it is ordinarily necessary to make each product for a specific physical and chemical use, and industry has generally succeeded in solving such problems.

Operating difficulties encountered in early stages now largely overcome.

#### LIABILITIES

Little is known about chemistry of final stages of polymerization leading to resinification.

New tools for measuring rate and degree of chemical reaction and physical complexity of the product required.

Physical control further advanced than chemical.

Inter-relationship between chemical reactants and physical properties of resins incompletely established.

Continuous processes not yet developed.

## FRIEDEL AND CRAFTS

By P. H. GROGGINS

The marked decline in the price of anhydrous aluminum chloride has stimulated research and technical operations based on the Friedel and Crafts reaction. It is not generally recognized that this process provides a useful and practical tool for the synthesis of almost every class of compounds. The reaction is employed for the manufacture of keto acids, anthraquinone and its derivatives, ketones, carboxylic acids, aldehydes, hydrocarbons, and others.

Investigations of the mechanism of the Friedel and Crafts reaction have been of great value not only in advancing the art in this field but also in contributing to our knowledge of the mechanism of other unit processes.



It is generally recognized that addition of aluminum chloride to a comparatively unsaturated component takes place. This addition complex exhibits salt-like properties and in solution is a conductor, the conductivity increasing with increasing concentration of the complex. (Wertyporoch et al., *Ber.*, Vol. 66, 1933, p. 1232.)

The behavior of aluminum chloride as a catalyst or condensing agent is directly related to the constitution of the product formed after stabilization, i.e., splitting off of HCl. In catalytic reactions the end product does not exhibit pronounced unsaturation and does not therefore bind the  $AlCl_3$ . No satisfactory methods have been evolved for removing the desired condensation product from the added aluminum chloride and leaving the latter in a reactive form.

The inter-relationship of carboxylic acids, acid chlorides and acid anhydrides has recently been explored. This new field of research (P. H. Groggins, R. H. Nagel, and A. J. Stirton: To be reported soon) still requires considerable study.

The influence of halogen compounds and halogen carriers in conducting Friedel and Crafts reaction has been given consideration. The studies need to be correlated with the unit process of halogenation.

In a number of Friedel and Crafts syntheses the chemical and physical factors involved have been explored. Extensive research in this field is still necessary, because the principal product is generally contaminated with more or less byproducts.

Use of the reaction in the condensation of phenols requires extensive study.

In the design and construction of equipment, little has been done since Stone and Jacobson (U. S. P. 1,656,575) introduced the mill-type reactor for carrying out reactions involving approximately the combining proportions of the reactants. In the light of recently published studies (P. H. Groggins and R. H. Nagel, *Ind. Eng. Chem.*, 25, 1083, 1933) on this subject it appears that considerable progress can be made in this field.

## POLYMERIZATION

By A. J. NORTON

The comparatively recent conception of polymerization as a unit process has opened a new line of thought among industrial chemists. Previously, polymerization was considered to be an in-

cidental tool and was studied as a result rather than a cause. Viewed as a unit process, with numerous, inter- and intra-relationships, it gives a new basis for the development of the plastics industry.

Physico-chemical explanations of the structure of matter have paved the way for a better understanding of polymerization reactions, and have been instrumental in the replacement of rule-of-thumb methods by scientific control. A new and rapidly growing industry, that of synthetic resins, is based on this unit process. Unlike those of natural resins, the properties of synthetic resins are susceptible to infinite variations to meet almost any new requirements.

Great advances in the preparation of thermosetting resins of all types, and new types of resins for use in finishing coats, both by themselves and in combination with oil and cellulose esters, have been made. New industries, such as the development of a synthetic lumber, are growing out of the use of such products. Much detailed information is lacking regarding the technique of manufacture due to the nature of the industry.

Many new and important developments have resulted from the large amount of intensive work being done in this field, and a future expansion of the industry appears assured.

## CERAMISTS AND ELECTROCHEMISTS MEET IN ASHEVILLE

A LARGE representative group of members and guests from both the American Ceramic Society and the Electrochemical Society met at Asheville, N. C., April 26 to 28. There were a number of subjects of immediate interest to both societies and accordingly discussions were often long and heated. Dr. John Johnston of the Electrochemical Society opened the 65th convention of the society and turned the chair over to Prof. Charles P. Smyth of Princeton University, an authority on dielectrics.

### Liquid and Solid Dielectrics

There was a splendid array of papers on this subject of ever increasing technical importance. With the rapid growth in the generation and utilization of electricity the demands upon the chemist and ceramist for better dielectric or insulator materials has proceeded much faster than the supply. The dominating influence of the newer plastics is keenly felt by the manufacturers of the older

so-called "standard" insulating materials. Prof. J. B. Whitehead of Johns Hopkins in his paper on liquid dielectrics emphasized the great need of more exact data. Very little is known about the ions involved either in the conductivity of liquid dielectrics or of the large dipoles which contribute substantially to the dielectric loss. The discussion further emphasized the importance of ascertaining the fundamental reason why one substance such as water should have a dielectric constant of almost 80 and another substance, paraffin oil, a constant less than 6. It was generally felt that a better understanding of dielectric behavior, coupled with our modern physical methods for studying the molecule, would lead to the discovery of entirely new materials.

Prof. Vladimir Karapetoff of Cornell in referring to liquid organic dielectrics and molecular structure called attention to certain important esters such as olive oil and castor oil. These are suitable for electrical insulating purposes be-

cause of their high molecular weight, high boiling point and chemically closed molecular structure. F. M. Clark of the Pittsfield plant of the General Electric Co. in his paper on the synthetic liquid dielectrics described the application of chlorinated aromatic molecules which contain at least a chemical equivalent of chlorine and hydrogen. Pentachlorodiphenyl alone or with trichlorobenzene was found to be superior in many respects to mineral oil. There is no potential fire or explosion risk; it has a high chemical stability, is non-oxidizing and non-sludging and has a higher dielectric constant.

New rubber-like compounds were reported upon by H. Eugene Mason of Ridgewood, N. J. Experiments showed that insulation affording the highest dielectric strength does not imply that that insulation will have the longest life in service. Accelerated life tests are often deceiving. There is a simple exponential relation between the life of the insulating material and the breakdown voltage.

A study of alkyd resins, in particular the glycerol phthalate type, was made by R. H. Kienle and H. H. Race of Schenectady. In presenting the results Race stated that alkyd resins may be

hard, rigid, soft, balsam-like, flexible and rubbery. Such alkyd resins as are typical of the more common states were prepared and investigated. During the formation of unmodified alkyd resins, there occurs a progressive increase in electrical resistance with time, temperature of preparation being constant. No abrupt change in resistance was obtained with the heat convertible resins as they gelled. Mobility is shown to be an important factor in influencing the resistance of a resin during formation since the heat convertible resin shows a much higher resistance for a given per cent esterification than does the heat non-convertible resin. It is suggested that electrical resistance may be conveniently used to study and follow resin formation.

#### Electric Firing of Ceramics

The round table discussion on Thursday at noon was in charge of the Ceramic Society, Pres. W. Keith McAfee presiding. He called upon Perry D. Helser of the General Ceramics Co. to start the discussion. The pros and cons of electric vs. gas firing of ceramic ware were presented rather forcefully by a dozen different participants, including S. T. Henry of Spruce Pine, N. C., A. V. Bleininger of Newell, W. Va., Colin G. Fink of Columbia, R. C. Benner of the Carborundum Co., J. C. Hostetter of Corning Glass Works, E. C. Sprague of Acheson Graphite Co., John B. Glaze of the Norton Co., F. C. Frary of the Aluminum Co., T. F. Baily of Alliance, O., Ross C. Purdy, Secretary of the Ceramic Society, and F. H. Riddle of the Champion Spark Plug Co. And although Purdy caused much merriment with his "We don't want any electric toasters!" it was generally felt that with better and higher temperature resistor material available and radical changes in design of kilns, electric firing warrants further study and trial. Decided progress has already been made in Europe. The following Electro-ceramic Research Committee was appointed to supervise and direct pilot plant tests on electric firing: Perry D. Helser (chairman), S. T. Henry (executive secretary), A. V. Bleininger, Colin G. Fink and A. E. Greaves-Walker.

An informal dinner was served at which Dr. A. H. Morgan, past-president of the University of Tennessee, now a director of the T.V.A., discoursed on the social and industrial aspects of the Tennessee Valley project. Then followed the presentation of the annual Electrochemical Society's prize to young authors to Bruce L. Bailey of the Norton Co., co-author of the paper on hardness values for electrochemical products.

Dr. S. O. Morgan of the Bell Telephone Laboratories, an active participant in the dielectric symposium, discussed two types of dielectric polarization. Dr. George W. Morey of the Geophysical Laboratory at Washington presented a fine review of the present status of glass as a dielectric. The anomalous dispersion in crystalline solids was reported upon by C. E. Sun and J. W. Williams of the University of Wisconsin.

Dr. L. J. Buttolph of the General Electric Vapor Lamp Co., outlined the principal factors that contributed to the development of gaseous conduction lamps, resulting in the new mercury arc and sodium vapor lamps now rapidly displacing the tungsten lamp in highway lighting. Then followed a paper by G. B. van de Werfhorst of the Philips Co., Eindhoven, Holland, presented by Dr. L. P. Graner who had imported for the occasion a number of Dutch lamps to illustrate the development of gaseous discharge lamps in Europe. In the development many difficulties were encountered. The automatic ignition of the sodium vapor lamp was solved by the introduction of a small amount of neon gas and the use of a hot cathode. The disintegration or devitrification of ordinary glass by the hot sodium vapor was remedied by the substitution of a borosilicate glass. Of particular interest is the three phase 300 watt sodium lamp, the lighting efficiency is three to five times that of the tungsten lamp.

Prof. Greaves-Walker presided at the refractories session on Friday morning which was in charge of the Ceramic Society. R. L. Melton, K. W. Brownell and G. J. Easter of the Carborundum Co. reported upon the effect of moisture on the electrical leakage through typical resistor embedding cements. A second paper by representatives of the Carborundum Co., Chas. McMullen, A. A. Turner and G. J. Easter, covered a study of the resistance of fused refractory materials to metallurgical slags.

H. K. Richardson of the Westinghouse Lamp Co. reported on the casting of small thoria crucibles from a slip made according to ceramic practice. Small additions of cryolite and zirconia facilitated manufacture. Firing was done at 1,920 deg. C. The porosity is small, 0.03 per cent. The melting point is above 2,300 deg. C. In answer to W. W. Winship's question Dr. Richardson stated that all of the cryolite is expelled during firing.

An investigation of eleven types of insulating brick was made by W. C. Rueckel of Ohio State University. He submitted a critical discussion of formulas for permeability.

A long and lively discussion followed M. A. Baernstein's presentation of a new and improved electric furnace.

When a mixture of witherite with a 10 to 20 per cent addition of a special, fused BaO is introduced into a high-temperature electric furnace: The acid linings are protected; spalling ceases; absorption of Si and silicates is prevented; metals are freed from occlusions; white cast iron is improved in quality; likewise low carbon steels; the atmosphere of the furnace is conditioned, the arc sustained and the metal quieted; slags are made more fluid and slag inclusions avoided; introduction of carbon into an alloy is aided; quality of product is easily controlled. The barium is added 20 min. before poring. Ba ferrites and silicates are formed. The barium stops or retards the action of the furnace gases on the refractories. Just enough is added to form a perfect glaze. Next, E. J. Bogner of the Corundite Refractories, Inc., presented a classification of insulating refractories.

The final paper of the session was by V. L. Mattson, manager of the Celomines. He described his plant in Yancey County, N. C., where high-grade cyanite is produced. A combination of induction-magnetic and electrostatic separators removes some 20 minerals associated with the cyanite. Friday afternoon was spent in visiting the Mattson plant and the mill of the United Feldspar Corp. A complimentary luncheon was served at which Dr. Harry C. Curtis gave a presentation of his T.V.A. work, in particular that on phosphates.

#### Hiram S. Lukens Elected President

At the annual business meeting Secretary Fink reported upon the healthy condition of the Society's finances; the selection of P. A. Jacquet of Paris as the seventh Weston Fellow, who will conduct his researches under Dr. Chas. Marie in Paris; the general revival of the various branches of electrochemistry as indicated by the dozen reports prepared by the scientific and technical committees of the Society; the receipt of contributions from C. G. Schluederberg of the Westinghouse company and B. H. Jacobson of the E. C. Klipstein Co. to the Roeber Research Fund bringing the capital fund up to \$2,000; the splendid work of the membership committee, H. C. Cooper, chairman. In conclusion President Johnston presented the report of the tellers of election. The following officers were elected: Hiram S. Lukens, president; R. L. Baldwin, Niagara Falls, Alexander Lowy, Pittsburgh, G. W. Heise, Cleveland, J. H. Critchett, New York, vice-presidents; L. R. Westbrook, Cleveland, S. Swann, Urbana, Ill.; J. J. Mulligan, East Chicago, Ind., managers; R. M. Burns, treasurer; Colin G. Fink, secretary.



## CHEMICAL ENGINEERS MEET IN NEW YORK

THE twenty-sixth semi-annual meeting of the American Institute of Chemical Engineers was held in New York, May 14-16. The technical papers were concerned with the principles of chemical engineering and with applied chemical engineering. Students of chemical engineering were given a special session of their own on the second day of the convention.

The convention opened on Monday morning with several papers on applied chemical engineering. The first of these was on the applications of phenolic plastics in the chemical industries by William H. Adams, Jr., technical director, Haveg Corp. For several years this type of synthetic resin has been used as a material of construction for equipment. Spinning buckets and bucket covers, and driving gears on the viscose pumps of the spinning machines are among the applications in the rayon industry which was one of the first process industries to recognize the possibilities of the laminated resinous material. Other chemical industries have taken advantage of the corrosion resistance to use it for many applications. About two years ago the Haveg Corp. started producing large pieces of process equipment from the phenolic resinoid with an asbestos or other filler. (See *Chem. & Met.* Vol. 40, p. 201).

### Chemicals in Petroleum Refining

The second paper on the program was on the trend of chemical utilization in petroleum refining. The authors were P. C. Keith, Jr., and H. O. Forrest of the N. W. Kellogg Co. The three products of major importance requiring well over 90 per cent of all chemicals are gasoline, kerosene, and lubricating oil, and the general trend of chemical utilization is defined by them. For this reason most of the discussion in this paper was limited to the chemical treatment of these products as practiced in 1920 and as developed up to the present time. Carleton Ellis of Montclair, N. J., closed this technical session with a discussion of the prospects of a petroleum chemical industry. These three papers will be published in full in the June number of *Chem. & Met.*

The second session on applied chemical engineering was opened by R. Lyman Heindel, Jr., the Dow Chemical Co., with a discussion of industrial developments in heat transfer with organic compounds. According to Heindel the eutectic mixture of di-

phenyloxide and diphenyl is the most practical heating medium for operation at temperatures in the range 450-750 deg. F. This is generally above the practical upper limit for steam and below the most desirable temperatures for mercury. Applications of Dowtherm (organic heat transfer fluids) to power cycles were discussed with reference to air preheating, heat storage and the superheat and resuperheat of steam. The use of indirect heating media in some existing industrial processes was outlined. The boilers were described and desirable precautions were listed. A complete system, in which such heating media are used for both the distillation and the condensation of other high boiling compounds, was illustrated. A variety of uses for such products were suggested by the speaker.

### Mercury Vapor in Process Industries

Charles A. Hulsart of Babcock & Wilcox Co. discussed the applications of mercury vapor in the process industries. The light temperature attainable by saturated vapors of mercury which enables the user to take advantage of the heat developed when it condenses to a liquid makes it a valuable material of heat transfer. Mercury can be used up to as high as 1,000 deg. F.

The final paper of the session was on the stroboscope and the high-speed motion picture camera as research instruments. It was prepared by Harold E. Edgerton and Kenneth J. Germeshausen of M.I.T.

The session on principles of chemical engineering was in charge of Harry A. Curtis, vice-president of the Institute. A feature was the symposium on fractional distillation. The first paper was a discussion of the methods for determining the number of equilibrium plates, by George Granger Brown and Mott Souders, Jr., University of Michigan. The second paper was concerned with theoretical comparison of methods of calculation, by the same two authors with the cooperation of W. W. Hesler. While the application of theoretical methods of calculation to commercial gasoline stabilized test data were discussed by E. G. Ragatz, H. V. Nyland, Souders and Brown.

Purification and separation of two liquids originally mixed together by distillation and a series of vaporizations and condensations in a column made up of plates connected by short tubes covered with perforated cups were

discussed by J. S. Carey, Alco Products Co.; J. Griswold, Pure Oil Co.; W. H. McAdams and W. K. Lewis, M.I.T. The title of their paper was Plate Efficiencies in Rectification of Binary Mixtures.

Inefficient separation of the several constituents of a liquid mixture by distillation is frequently caused, according to George E. Holbrook, of E. I. du Pont de Nemours & Co., and Edwin M. Baker, of University of Michigan, by the fact that droplets of the original mixture are carried along with the vapor through the still. The extent of this contamination of the product is related to the way in which the equipment is operated as well as to its original design. The subject has been carefully studied and methods of operation reduced to mathematical formulas for the guidance of both designers and operators.

Solution cycles was the subject of a paper by William H. Sellew of the University of Michigan. The paper by Professor Sellew analyzes the use of solutions made up of two or more components for the production of power or refrigeration and shows that because of the greater temperature differences the efficiency is much greater. The use of solutions makes possible the fulfillment of certain conditions of a perfect cycle which is not possible with a single liquid.

Two papers covering studies in agitation were presented by A. McLaren White, head of the department of chemical engineering at the University of North Carolina with the assistance of three of his graduate students, Edward Brenner, G. A. Phillips and M. S. Morrison. The subjects of the papers were power measurements and the correlation of power data. While agitation and mixing by moving paddles and similar devices is a common chemical engineering operation, very little is known concerning power requirements as applied to the design of such equipment. Professor White has measured the power requirements of paddle stirrers in tanks of different size and shape with liquids of varying densities and at different speeds.

### Silk Throwing Industry

Chemical engineering in the silk throwing industry was the subject of a paper by Dale S. Chamberlin of the National Oil Products Co. He stated that many advances have been made in the application of colloidal chemistry in the lubrication and softening of yarns; and with the development in chemical engineering of drying, conditioning, wettingout and twist setting, the throwster has come to appreciate chemistry and engineering as a tool for producing better yarns.



# NEWS OF THE INDUSTRY

**Revenue Bill signed by President with inclusion of clause placing import duty on Philippine coconut oil. Phosphate rock mined on land controlled by TVA and shipped to Muscle Shoals. Code for chemical engineering equipment ready for official signature. President of Harvard University awarded medal of the American Institute of Chemists.**

---

## Chemical Equipment Code Nears Adoption

CHEMICAL engineering equipment code matters were further advanced by formal hearing, and post-hearing conferences with N.R.A., on April 27. On that occasion there was general acceptance and evidence of probable adoption of the Chemical Engineering Equipment Industry code as a subdivision of the Machinery and Allied Products Industry code. Preparation and presentation of this sub-code was by a committee working under the chairmanship of James E. Moul, of Turbo-Mixer Corp.

Obstacles to immediate and complete adoption of this code governing trade practices rested largely on features of phraseology, most of which could readily be adjusted at the informal conference. Major obstacles presented were directed against the definition of the industry. The Construction Industry, and its subdivision of General Contractors, objected particularly to the unqualified definition of "design, engineering, erection" of this type of equipment as a part of the Chemical Engineering Equipment Industry. The argument was that such statement unqualified would unduly overlap the construction code and might interfere with the scope of contractors' activities in dealing specially with this type of industrial equipment.

Question was also raised by Dr. Walter A. Schmidt, Western Precipitation Co., Los Angeles, as to the propriety of including in the definition the "licensing" of "processes." He cited the possibility that under such a provision research laboratories and inventors having nothing to do with machinery or equipment in competition with the principal members of the industry, would, under a generous reading of this definition, be regulated. It was evident that inclusion of certain such activities was desired by the manufacturers, and a modified phraseology adopted to cover the desired portion of this sort of activity.

## Institute Medal Awarded To Dr. J. B. Conant

THE medal of the American Institute of Chemists, presented annually for outstanding service to chemistry in America, has been awarded this year to Dr. James Bryant Conant, president of Harvard University. The award is made in recognition of Dr. Conant's many contributions to chemical science.

Dr. Conant has done notable work in establishing the chemical structure of many complicated organic compounds, including among others, haemoglobin of the blood substance, chlorophyll, the

green coloring matter found in plant life, and a number of other coloring substances.

Dr. Conant has applied a new point of view to study concerning well-known chemical reactions, determining the energy changes involved and the energy levels at which the reactions occur. He has devised new methods of laboratory technique for better understanding of the mechanism of organic chemical reactions, as well as new modes of attack upon molecules for a deeper insight into the impelling forces which cause reactions.

## Southern Chemical Corp. Enters Chemical Field

UNDER date of April 7, a charter was granted at Wilmington, Del., to the Southern Chemical Corp. The new corporation which has qualified to do business in Texas was formed jointly by American Cyanamid Co. and Pittsburgh Plate Glass Co. It will produce a varied line of chemicals in connection with the operation of the alkali plant being constructed at Corpus Christi, Tex., by Southern Alkali Corp., also jointly owned by the two above-mentioned companies.

The officers of Southern Chemical Corp. are as follows: W. B. Bell, chairman; H. L. Derby, president; C. M. Brown, vice president; K. F. Cooper, vice president; H. A. Galt, vice president; H. S. Wherrett, vice president; R. C. Gaugler, treasurer; A. B. Savage, assistant treasurer; K. C. Towe, assistant treasurer; W. P. Sturtevant, secretary; J. H. Heroy, assistant secretary; G. R. Martin, assistant secretary.

## Organic Products Sought For Spray Materials

THE Department of Agriculture will broaden its search for substitutes for lead arsenate and other poisonous spray materials now in general use to protect fruit and vegetables from insects.

Three bureaus, the Bureau of Entomology, the Bureau of Chemistry and Soils and the Bureau of Plant Industry, will participate in the enlarged program. Dr. E. N. Bressman, formerly of the Oregon Agricultural Experiment Station, will coordinate the work of the three bureaus in this investigation.

The most important part of the entomological work will be field testing of several organic materials such as rotenone, pyrethrum and nicotine which in past experiments have shown promise as substitutes for lead arsenate. These organic compounds are believed to be not harmful to human health when present in the quantities that would be found on harvested fruit.

# PROGRESS IN CHEMICAL CODE

**A**DMINISTRATION of the code of fair competition for the chemical manufacturing industry, as finally approved by the President on Feb. 10, has been strengthened by the appointment, as permanent director, of Dean Clark, prominent industrial engineer of New York. He succeeds Howard Huston of the American Cyanamid Co., who has served in a temporary capacity since the organization of the Chemical Alliance, Inc. The new code director has opened offices in the Rockefeller Center in New York.

Acceptance of the Chemical Code on the part of a predominating proportion of the chemical manufacturing industry is, of course, the first step toward its practical application and enforcement. The encouraging progress which has been made in that direction is indicated by the following lists of chemical companies, compiled by Director Clark's office to show the status of code as of May 15, 1934. It will be observed that most of the members of the Chemical Alliance, Inc., have indicated their assent and in addition fifteen non-member concerns have accepted the code but

have not yet joined the Alliance. Presumably there are other firms in the industry that are now complying with the various provisions of the code but have not officially recorded their assent with the code director. It would seem that such a step is desirable if true self government is to be applied in the administration and enforcement of the code.—EDITOR.



New Code Eagle  
(That for chemical manufacturing industry not yet released)

**List A**—Members of the Chemical Alliance. All except those starred have assented to the Code of Fair Competition for the Chemical Manufacturing Industry.

**List B**—Firms which have assented to the Code of Fair Competition for the Chemical Manufacturing Industry but which have not yet joined the Chemical Alliance.

## LIST A

Althouse Chemical Co., Reading, Pa.  
Amalgamated Dyestuff & Chemical Wks., Inc., Newark, N. J.  
American Agricultural Chemical Co.,\* New York  
American Aniline & Extract Co., Inc., Philadelphia, Pa.  
American Chemical Products Co., Rochester, N. Y.  
American Commercial Alcohol Co.,\* New York  
American Cream Tartar Co., Los Angeles, Calif.  
American Cyanamid & Chemical Corp., New York  
American Cyanamid Co., New York  
American Doucil Co., Philadelphia, Pa.  
American Dry Ice Co.,\* New York  
American Dyewood Co., New York  
American Glycerin Co., Wilmington, Del.  
American Lanolin Corp., Lawrence, Mass.  
American Norit Co., Cleveland, Ohio  
American Platinum Wks., The, Newark, N. J.  
American Potash & Chemical Corp., New York  
American Powder Co., New York  
American Tar & Chemical Co. (of Duluth, Minn.), Montreal, Canada  
American Tar Products Co. Inc., Pittsburgh, Pa.  
Ames Chemical Works, Inc.,\* Glens Falls, N. Y.  
Anchor Color & Gum Works, New York  
Ansbacher Siegel Corp., New York  
Ansil Chemical Co., Marinette, Wisc.  
Apache Powder Co., Benson, Ariz.  
Arizona Chemical Co., New York  
Arkansas Chemical Co., Inc., New York  
Armour Ammonia Wks.,\* Chicago, Ill.  
Armour Fertiliser Wks., Atlanta, Ga.  
Arnold, Hoffman & Co., New York  
Atlas Powder Co. and subsidiaries, Wilmington, Del.  
Austin Powder Co., Cleveland, Ohio.

Bakelite Corp., New York  
J. T. Baker Chemical Co., Phillipsburg, N. J.  
Baker & Co., Inc., Newark, N. J.  
Barium Products, Ltd., New York  
Barium Reduction Corp., Charleston, W. Va.  
Barnes Chemical Wks., Inc., Paterson, N. J.  
Bates Chemical Co., Lansdowne, Pa.  
Baugh Chemical Co.,\* Baltimore, Md.  
Bay Chemical Co., New Orleans, La.  
Belle Alkali Co., Belle, W. Va.  
Benzol Products,\* Newark, N. J.  
Blockson Chemical Co., Joliet, Ill.  
The R. H. Bogle Co., Alexandria, Va.  
Bopf-Whittam Corp., Westfield, N. J.  
Borax Union, Inc., San Francisco, Calif.  
Henry Bower Chemical Co., Philadelphia, Pa.  
Henry Bower Chemical Mfg. Co., Philadelphia, Pa.  
Brush Beryllium Co., Cleveland, Ohio.  
Brush Development Co., Cleveland, Ohio.  
Brush Laboratories Co., Cleveland, Ohio.  
Buckeye Cotton Oil Co., Pulp Department, Memphis, Tenn.  
Buckeye Soda Co., Painesville, Ohio.  
Buffalo Electro Chemical Co., Buffalo, N. Y.  
The Burnley Battery & Manufacturing Co., North East, Tenn.  
The Burton Explosives, Inc., Cleveland, Ohio.

Calco Chemical Co., Bound Brook, N. J.  
California Cap Co., Oakland, Calif.  
California Carbonic Co., Los Angeles, Calif.  
California Chemical Corp., New York  
California Spray-Chemical Corp., Berkeley, Calif.  
Carbide & Carbon Chemicals Corp., New York  
Carbonic Manufacturing Corp., New York  
Carter Bell Mfg. Co., New York  
Catalazuli Manufacturing Company, Inc., College Point, N. Y.  
Catalin Corporation of America, New York  
Celluloid Corp., Newark, N. J.  
Central Chemical Co.,\* Chicago, Ill.  
Chemical Manufacturing Co., Inc., Ashland, Mass.  
Chemical Reduction Co., New York  
Chipman Chemical Co., Inc., Bound Brook, N. J.  
Church & Dwight Co., Inc., New York  
Citro Chemical Co. of America, Maywood, N. J.  
Coast Manufacturing & Supply Co., Livermore, Calif.  
Coleman & Bell, Norwood, Ohio.

Columbia Alkali Co., Barberton, Ohio.  
Commercial Solvents Corp., New York  
Commonwealth Color & Chemical Co., Brooklyn, N. Y.  
Consolidated Chemical Industries Inc., San Francisco, Calif.  
Consolidated Color & Chemical Co., New York  
Coopers Creek Chemical Co., West Conshohocken, Pa.  
Copper Pyrites Corp., New York  
Croton Chemical Corp., Brooklyn, N. Y.  
Crowley Tar Products Co., New York  
Crystonix Manufacturing Co. Inc.,\* Brooklyn, N. Y.  
Curtin-Howe Corp. of Del., New York  
Curtin-Howe Corp. Ltd., New York  
Curtin-Howe Corp. of New York, New York.

Darvin & Nord, Inc.,\* Newark, N. J.  
Henry K. Davies & Co., Inc.,\* New York  
Davies Nitrate Co., Inc., Brooklyn, N. Y.  
The Davison Chemical Co.,\* Baltimore, Md.  
Dearborn Chemical Co., Chicago, Ill.  
Deepwater Chemical Co., Ltd., Compton, Calif.  
Dehls & Stein,\* Newark, N. J.  
J. A. Denn Powder Co., Portland, Ore.  
The Martin Dennis Co., Newark, N. J.  
Detroit Chemical Wks., Detroit, Mich.  
Detroit Soda Products Co., Wyandotte, Mich.  
Dewey & Almy Chemical Co., North Cambridge, Mass.  
Diamond Alkali Co., Pittsburgh, Pa.  
Dominguez Chemical Co., Los Angeles, Calif.  
Dow Chemical Co., Midland, Mich.  
Dowell Incorporated,\* Midland, Mich.  
F. F. Drakenfeld & Co.,\* Inc., New York  
Ducktown Chemical & Iron Co., New York  
Ducktown-Pyrites Corp., New York  
E. I. DuPont de Nemours & Co., Inc., Wilmington, Del.  
DuPont Viscoloid Co., New York  
Durite Plastics, Philadelphia, Pa.

Egyptian Powder Co.,\* East Alton, Ill.  
Electric Smelting & Aluminum Co., Cleveland, Ohio.  
Electro Bleaching Gas Co., New York  
The Ensign Bickford Co., Simsbury, Conn.  
The Equitable Powder Manufacturing Co.,\* East Alton, Ill.  
Ethyl-Dow Chemical Co.,\* Midland, Mich.

The Fiberloid Co., Indian Orchard, Mass.  
Fields Point Manufacturing Corp., Providence, R. I.  
J. B. Ford Co., Wyandotte, Mich.  
Franco-American Chemical Wks.,\* Carlstadt, N. J.  
Franks Chemical Products Co., Brooklyn, N. Y.  
George G. Fries & Co., Inc., New York.

Garden State Chemical Co.,\* Paterson, N. J.  
Garrett-Callahan Co., Chicago, Ill.  
General Atlas Carbon Co., New York  
General Dyestuff Corp.,\* New York  
General Explosives Corp., New York  
General Plastics Inc., North Tonawanda, N. Y.  
General Salt Co., Ltd., Los Angeles, Calif.  
Giant Powder Co., Wilmington, Del.  
Givaudan Delawanna Inc., New York  
Glyco Products Co.,\* Inc., Brooklyn, N. Y.  
James Good, Inc.,\* Philadelphia, Pa.  
Grasselli Chemical Co., Cleveland, Ohio.  
Great Western Electrochemical Co., San Francisco, Calif.

Halowax Corp., New York  
Hanovia Chemical & Manufacturing Co.,\* Newark, N. J.  
A. Harrison & Co., Inc., Pawtucket, R. I.  
The Harshaw Chemical Co., Cleveland, Ohio.  
Hartman-Leddon Co., Inc., Philadelphia, Pa.  
Hercules Powder Co., Wilmington, Del.  
Herrick-Voigt Chemical Corp., Bayonne, N. J.  
Heyden Chemical Corp., New York  
Hoffman La Roche Inc., Nutley, N. J.  
Hooker Electrochemical Co., New York  
Hoover Color Corp., New York  
E. F. Houghton & Co., Philadelphia, Pa.  
E. F. Houghton & Co. of Mich., Philadelphia, Pa.  
Philip A. Hunt Co., Brooklyn, N. Y.  
Hydrox Chemical Co. of Illinois, Chicago, Ill.

# COMPLIANCE

Illinois Powder Manufacturing Co., St. Louis, Mo.  
 Illinois Western Cartridge Co.,\* East Alton, Ill.  
 Independent Coal Tar Co., Boston, Mass.  
 Industrial Chemical Corp. Ltd., New York.  
 Industrial Dyestuff Co., East Providence, R. I.  
 The Insel Co.,\* Arlington, N. J.  
 International Agricultural Corp.,\* New York.  
 Interstate Chemical Manufacturing Co., Jersey City, N. J.  
 Irvington Smelting & Refining Wks., Irvington, N. J.  
 Isco Chemical Co., Inc., Niagara Falls, N. Y.

Joanite Corp., Long Island City, N. Y.  
 Jones Chemical Co., Midland, Michigan.

Kavalco Products Co., Inc., Nitro, W. Va.  
 Kessler Chemical Corp., New York.  
 Kinetic Chemicals Inc., Wilmington, Del.  
 The King Powder Co., Cincinnati, Ohio.  
 Koppers Products Co., Providence, R. I.  
 Krebs Pigment & Color Corp., Newark, N. J.

Lacquer Chemicals, Inc., San Francisco, Calif.  
 Latimer Goodwin Chemical Co., Grand Junction, Colo.  
 Charles Lennig & Co., Inc., Philadelphia, Pa.  
 John D. Lewis Inc., Providence, R. I.  
 Liberty Powder Co.,\* East Alton, Ill.  
 Lindsay Light Co., Chicago, Ill.  
 The Liquid Carbonic Corp., Chicago, Ill.  
 Lockport Chemical Co., Pittsburgh, Pa.  
 Louisiana Chemical Co., Inc., San Francisco, Calif.  
 John Lucas & Co., Inc., Philadelphia, Pa.  
 Lucas Kiltone Co., Philadelphia, Pa.  
 Lucidol Corp.,\* Buffalo, N. Y.

A. R. Maas Chemical Co., Los Angeles, Calif.  
 Mallinckrodt Chemical Wks., St. Louis, Mo.  
 The Marquette Corp., Long Island City, N. Y.  
 Marine Chemicals Co., Ltd., South San Francisco, Calif.  
 Maryland Chemical Co., Baltimore, Md.  
 The Mathieson Alkali Wks., Inc., New York.  
 Otto B. May, Inc., Newark, N. J.  
 Maywood Chemical Wks., Maywood, N. J.  
 The McGean Chemical Co.,\* Cleveland, Ohio.  
 Mechling Bros. Chemical Co., Camden, N. J.  
 Merck & Co., Inc., New York.  
 Merrimac Chemical Co. Inc., Boston, Mass.  
 Metal & Thermit Corp., New York.  
 Metasap Chemical Co., Harrison, N. J.  
 J. Meyer & Sons, Philadelphia, Pa.  
 Michigan Alkali Co., Detroit, Mich.  
 Midland Ammonia Co., Midland, Mich.  
 Milford Extract Co., Milford, Mich.  
 Monarch Chemical Co., New York.  
 Monsanto Chemical Co., St. Louis, Mo.  
 Mutual Chemical Co. of America, New York.

National Aluminate Corp., Chicago, Ill.  
 National Ammonia Co., Inc., Philadelphia, Pa.  
 The National Fuse & Powder Co., Denver, Colo.  
 National Kellastone Co., New York.  
 National Oil Products Co. Inc., Harrison, N. J.  
 National Pigments Co., St. Louis, Mo.  
 National Pigments & Chemical Co., St. Louis, Mo.  
 National Silicate & Chemical Co., Pittsburgh, Pa.  
 National Sulphur Co., New York.  
 Natural Products Refining Co., Jersey City, N. J.  
 The Naugatuck Chemical Co., New York.  
 New York Quinine & Chemical Wks., Inc., Brooklyn, N. Y.  
 Niacet Chemicals Corp., Niagara Falls, N. Y.  
 Niagara Alkali Co., New York.  
 Niagara Smelting Co., New York.  
 Niagara Sprayer & Chemical Co., Inc., Middleport, N. Y.  
 Nicotine Production Corp., Clarksville, Tenn.  
 Nixon Nitration Wks., Nixon, N. J.  
 The Northwestern Chemical Co., Wauwatosa, Wisc.  
 Novocol Chemical Manufacturing Co., Inc., Brooklyn, N. Y.

Oakite Products Inc.,\* New York.  
 The Oakland Chemical Co.,\* New York.  
 Oldbury Electro-Chemical Co., Niagara Falls, N. Y.  
 Otto Torpedo Co., Duke Center, Pa.  
 Owl Fumigating Co., Azusa, Calif.  
 Ozark Chemical Co., Tulsa, Okla.

Pacific Bone Coal & Fertilizing Co., San Francisco, Calif.  
 Pacific Coast Borax Co., New York.  
 Pacific R. & H. Chemical Corp., El Monte, Calif.  
 Pacific Silicate Co., San Francisco, Calif.  
 Paper Makers Chemical Corp., Kalamazoo, Mich.  
 Parker Rust-Proof Co.,\* Detroit, Mich.  
 M. W. Parsons, Imports & Plymouth Organic Laboratories, Inc., New York.  
 Patent Chemicals, Inc., Jersey City, N. J.  
 Pen-Chlor Inc., Philadelphia, Pa.  
 Pennsylvania Coal Products Co., Petrolia, Pa.  
 Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.  
 Peroxide Chemical Co., St. Louis, Mo.  
 Peroxide Mfg. & Specialty Co., New York.  
 Charles Pfizer & Co., Inc., New York.  
 Philadelphia Quartz Co., Philadelphia, Pa.  
 Philadelphia Quartz Co. of California, Ltd., Berkeley, Calif.  
 Phillips & Jacobs, Philadelphia, Pa.  
 Phosphate Products Corp., Richmond, Va.  
 Potash Company of America,\* Denver, Colo.  
 H. B. Prior Co., Inc., New York.  
 The Producers Torpedo Co., Marietta, Ohio.  
 Providence Drysalts Co., Providence, R. I.  
 Provident Chemical Works, Birmingham, Ala.  
 Pure Calcium Products Co., Painesville, Ohio.  
 Pure Carbonic Co. of America, New York.

Raffi & Swanson, Inc., Chelsea, Mass.  
 Rathbun Co., Inc., El Paso, Texas.  
 Robert Rauh, Inc., Newark, N. J.  
 Reilly Tar & Chemical Corp.,\* New York.  
 Reilly-Whiteman-Walton Co., Conshohocken, Pa.  
 The Resinous Products & Chemical Co., Philadelphia, Pa.  
 Resinox Corporation, New York.  
 Rhodes Alkali & Chemical Corp.,\* San Francisco, Calif.  
 Riverside Chemical Co. Inc., North Tonawanda, N. Y.  
 Rohm & Haas Co., Philadelphia, Pa.  
 Rossville Commercial Alcohol Co., New York.  
 Royal Baking Powder Co., New York.  
 Royce Chemical Co., Carlton Hill, N. J.  
 Rubber Service Laboratories Co., St. Louis, Mo.  
 Rumford Chemical Wks.,\* East Providence, R. I.

Salem Oil & Grease Co.,\* Salem, Mass.  
 Geo. H. Salzgeber, St. Louis, Mo.  
 San Francisco Sulphur Co., New York.  
 San Jose Spray Mfg. Co., San Jose, Calif.  
 Savell, Sayer & Co. Inc.,\* Lockport, N. Y.  
 J. Schnarr & Co., Orlando, Fla.  
 Schuykill Chemical Co., Philadelphia, Pa.  
 Sebs Chemical Co., New York.  
 The Selden Co., New York.  
 Seldner & Enequist, Inc., Brooklyn, N. Y.  
 The Sharples Solvents Corp., Philadelphia, Pa.  
 Shell Development Co., San Francisco, Calif.  
 The Shepherd Chemical Co., Cincinnati, Ohio.  
 The Sherwin-Williams Co., Cleveland, Ohio.  
 Sierra Magnesite Co. Ltd., New York.  
 Harold L. Simons, Inc., Long Island City, N. Y.  
 Smooth-on-Mfg. Co.,\* Jersey City, N. J.  
 Soluol Corp.,\* Providence, R. I.  
 Southern Chemical Cotton Co., Chattanooga, Tenn.  
 Southern Mineral Products Corp., New York.  
 The Sparkling Carbonic Co., Cincinnati, Ohio.  
 E. R. Squibb & Sons, Brooklyn, N. Y.  
 The Stamford Rubber Supply Co., Stamford, Conn.  
 Standard Chromate Co. Inc., Pittsburgh, Pa.  
 Standard Silicate Company, Pittsburgh, Pa.  
 Standard Ultramarine Co., Huntington, W. Va.  
 Stauffer Chemical Co., Los Angeles, Calif.  
 Stauffer Chemical Co. of Indiana, New York.

Stauffer Chemical Co. of Texas, New York.  
 Stauffer Chemical Co. of Virginia, New York.  
 Sterling Borax Co., Chicago, Illinois.  
 Sterling Products Co., Easton, Pa.  
 Charles H. Stone Chemical Wks., Charlotte, N. C.  
 The Sureshot Torpedo Co., Inc., Huntington, W. Va.  
 Swann Chemical Co., Birmingham, Ala.  
 The Swann Corp., Birmingham, Ala.  
 Synthetic Plastics Co. Inc., New York.

Tacoma Electrochemical Co., Philadelphia, Pa.  
 Tak, Inc., Newark, N. J.  
 The Tanglefoot Co.,\* Grand Rapids, Mich.  
 Taylor Chemical Corp. of Del., Philadelphia, Pa.  
 Taylor White Extracting Co., Camden, N. J.  
 Tennessee Copper Co., New York.  
 Tennessee Eastman Corp.,\* Kingsport, Tenn.  
 Texas Chemical Co., San Francisco, Calif.  
 Textile Products Co., Providence, R. I.  
 Titanium Pigment Co. Inc.,\* New York.  
 Tobacco By-Products & Chemical Corp., Louisville, Ky.  
 Toledo Synthetic Products Co., Inc., Toledo, Ohio.  
 The Tromite Corp., New York.  
 Tropic Chemical Wks., Panasoffkee, Fla.  
 The Trubek Laboratories, Inc.,\* East Rutherford, N. J.

United Chemicals Inc., New York.  
 United States Industrial Alcohol Co., New York.  
 United States Industrial Chemical Co., Inc., New York.  
 United States Potash Co., Inc., New York.  
 Unyte Corporation, New York.

Van Ameringen-Haebler, Inc., New York.  
 Van Dyk & Company, Inc., Jersey City, N. J.  
 Veritol Corp., Newark, N. J.  
 Verona Chemical Co., Newark, N. J.  
 Victor Chemical Works, Chicago, Ill.  
 Virginia Cellulose Department, Hercules Powder Co., Wilmington, Del.  
 Virginia Fertilizer Corp., St. Louis, Mo.  
 Virginia Smelting Co., Boston, Mass.  
 The Vitro Manufacturing Co.,\* Pittsburgh, Pa.  
 Vulcan Detinning Co., Seward, N. J.

The W-B Chemical Co.,\* New York.  
 The Warner Chemical Co., New York.  
 Warwick Chemical Co., West Warwick, R. I.  
 Washington Liquid Gas Co., Inc.,\* Seattle, Wash.  
 West Disinfecting Co., Long Island City, N. Y.  
 Western Powder Manufacturing Co.,\* East Alton, Ill.  
 Westvaco Chlorine Products Corp., New York.  
 Westvaco Chlorine Products, Inc., New York.  
 Wheeler, Reynolds & Stauffer Co., New York.  
 The White Tar Co. of New Jersey, Pittsburgh, Pa.  
 Wilckes, Martin, Wilckes Co., Birmingham, Ala.  
 Jacques Wolf & Co., Passaic, N. J.  
 The Wolff Alport Chemical Corp., Brooklyn, N. Y.  
 The Wood Ridge Manufacturing Co., New York.

J. S. Young & Co., Hanover, Pa.  
 J. S. Young Co., Baltimore, Md.  
 Zero Ice Corp., Detroit, Mich.

## LIST B

American Fluoride Corp., New York.  
 C. G. Buchanan Chemical Co., Cincinnati, Ohio.  
 Buco Products Co., Cincinnati, Ohio.  
 John Campbell & Co., New York.  
 W. C. Durfee Company, Inc., Boston, Mass.  
 The Edwal Laboratories Co., Chicago, Ill.  
 Felton Chemical Co., Inc., Brooklyn, N. Y.  
 Foote Mineral Co., Inc., Philadelphia, Pa.  
 Grange Powder Co., Seattle, Wash.  
 Peerless Color Co., Plainfield, N. J.  
 St. Louis Sulphur & Chemical Co., St. Louis, Mo.  
 Seydel & Co., Jersey City, N. J.  
 Van Schaack Bros. Chemical Wks., Chicago, Ill.  
 Young Aniline Works, Inc., Baltimore, Md.  
 California Soda Co., Oakland, Calif.



**C**HEMICAL industries promise to lead the way out of the depression. This is the conviction of competent observers in Washington. They reason in this way. Relatively greater progress has been made during the last year by most chemical industries than by other manufacturing industries. Unemployment among chemists has been reduced by one-half during the past twelve months. Many more jobs are being made available this year to students leaving college.

Amendment of the securities act and the certainty that there can be no blighting legislation for nearly a year, at least, are expected to release the pent-up potentialities of the industry. Because of the uncertainties in the business situation three years have passed in which few of the many chemical patents granted have been exploited.

For thirteen years after the war the American chemical industry distinguished itself particularly in the application of practical commercial ideas. For three years the tendency has been to suppress anything in the way of a venture. Now that the outlook is more stable and money for financing is available, decided acceleration of most chemical industries is confidently predicted.

There is one cloud on the horizon. Under a reciprocal tariff it is feared that the chemical industry may suffer more than most other industries. Because of the youth of the industry high tariff rates in some instances have been necessary. Industries consuming chemical products are powerful and provide large employment. This means that great pressure will be brought to secure the reduction of some of these duties. More than that, Germany is one of the nations whose ability to buy American goods has been most greatly curtailed. There is certain to be an effort to build up our purchases in Germany, which carries with it the danger of a trade involving more imports of chemicals from Germany. Thinking at the moment in Washington, however, is toward the adjustment of the German balance of trade through agreements which will result in increased purchases of German goods by countries from which we buy raw materials.

#### **Vegetable Oil Tax**

Despite Presidential opposition to the new tax on imported vegetable oils, signature was affixed to the tax bill, including such levy. This places a new burden of 3 cents a pound under the guise of an excise tax, but actually a tariff, on the users of the major sorts of imported vegetable oils. Bad faith in our dealings with the Philippines is charged as a result. Even the President seemed to share this view, but apparently did not feel justified in throwing

## **NEWS FROM WASHINGTON**

By PAUL WOOTON

*Washington Correspondent  
of Chem. & Met.*



back to the wolves of Congress his hardly-achieved tax measure because it included this item.

The President has wanted an amendment of this feature on the ground of fair dealing with the Philippines which were promised that we would not change tariff burdens on their commodities during the interregnum between American control and complete independence. Such amendment will embroil Congress in bitter controversy, being loaded with dynamite because of the controversy over protection of domestic oil and fat producers, notably the dairy industry. Exploding such a charge in the face of prospective adjournment looks like bad politics, and is probably futile.

#### **Sugar**

Quotas for domestic sugar production, both beet and cane, are fixed by the new law which had Presidential approval May 9 but the Secretary of Agriculture will fix the quotas on imports from the territories and Cuba. Simultaneously with the enactment of this legislation, the President approved Tariff Commission recommendations reducing the import duty on Cuban raw sugar from 2 cents to 1.5 cents per pound, figured on a 96 degree purity. The new duty becomes effective June 8.

Under the new law sugar becomes a basic commodity under complete A.A.A. regulation. A processing tax will be levied for compensation of domestic cane and beet growers for their co-operation in staying within the allotted production quotas. It is expected that the consumer price of sugar will not be changed by these developments, the lowering of the tariff being intended just to offset the processing tax.

#### **Tin**

Alarmed by the depletion of domestic tin stocks, industrial groups petitioned the President to embargo exports of scrap tin plate under the provisions of N.R.A. Under a Justice Department ruling that Presidential authority was

not adequate for this purpose, the scene of effort shifted to Congress. The first legislative proposals were to limit exports by permit. Later recommendation was that the United States accept tin from Britain and other debtor nations in lieu of cash or token payment.

Big domestic tin users, especially can companies, are supporting the project. State, Commerce, and War Departments are enthusiastic for anything that will increase American tin supplies without offending European nations. Unexpectedly vigorous support has been discovered for the philosophy of accepting tin from Britain. Both nations might profit under such a deal. A congressional committee of investigation is proposed. Japan, the original scrap purchaser causing the trouble, has run scrap tin plate prices up to "alarmingly high levels."

Mining of phosphate ore from farmland in central Tennessee on which TVA has contracted for mineral rights is under way. Ore is being shipped to the fertilizer plant at Muscle Shoals preparatory to smelting upon completion in July of alterations and additions at Nitrate Plant No. 2. Tests of new forms and combinations of fertilizer are being made as a basis for production and distribution inside and outside of the Valley.

Opposition to a one-man tariff doesn't seem to count when that man is President Roosevelt. The administration has enough votes in the Senate and the prospect of a successful filibuster is remote. Any amendments by the Senate to make it more palatable to opponents probably will go by the board when the bill goes back to the House. The bill has few real friends but the administration has cracked the whip and the only consolidation to objectors is that the arbitrary power given to the President may prove to be his undoing. They regard as a mere gesture the provision for public notice of intention to negotiate an agreement in order that any interested person may have an opportunity to present his views.

The President will hold in the palm of his hand industries in any way dependent on tariff protection. If they squawk about anything that follows in the train of NRA or other business control measures he can squeeze. As for the advantage to be gained in export trade, Harry L. Derby, vice president of American Cyanamid Company and chairman of the Tariff committee of the Manufacturing Chemists Association, told the Senate Finance Committee that foreign consumers will buy our products if it is to their advantage to do so but that he doesn't believe any trade can be made that will result in their buying American products if it is not to their advantage from the standpoint of quality, price and other factors.

# MARKETS

Despite heavy stocking up of chemicals in the latter part of last year, contract withdrawals for the first quarter of this year far outstripped those for the corresponding quarter of 1933. The fertilizer and textile trades have cut down raw material requirements in the last month and buying for soap account promises to encounter slow period.

WITH THE majority of large consumers of chemicals covered by contracts, the degree of activity in the market is measured more by the volume of contract withdrawals than by buying for new account. In most cases, call for deliveries has been satisfactory. Automotive, metallurgical, glass, plastics, paint and varnish, and rubber requirements for raw materials have been of an expanding nature. Fertilizer chemicals have passed their active season and labor troubles tended to restrict consumption of chemicals for rayon manufacture. Silk deliveries to mills fell off in volume in April and the silk trade promises to further restrict demand for chemicals in May due to a closing of mills for one week in order to cut down surplus stocks.

The chemical market at present, therefore, is spotted with some industries increasing their requirements and others cutting down. The accompanying table sets forth the activities in

chemical-producing and chemical-consuming industries for the first quarter of this year with comparisons for corresponding period of last year.

For the first time in some months the weighted index number for chemicals shows a decline. The most important price change was in the case of muriate of potash which was reduced substantially. Domestic production of potash is on the increase and foreign material from Spain and Russia has been competing with the French and German material so that competitive influences are regarded as responsible for the lowering in price.

The inclusion in the Revenue Bill of an import tax on coconut oil has been a factor for some time in the soap trade and has brought about an extended period of heavy buying of soap with a

## CHEM. & MET. Weighted Index of Prices for OILS AND FATS

Base = 100 for 1927

This month	56.94
Last month	57.13
May, 1933	52.37
May, 1932	40.40

The price movement for oils and fats was mixed with some selections commanding higher prices and others recording declines. The weighted number, however, moved downward largely due to the influence of cottonseed and palm oils.

corresponding increase in production. It is expected that this condition will remain in effect until the tax question has been definitely settled when a sudden cessation of buying orders is sure to follow because of the large stock accumulations which have been piling up.

Potash production last year amounted to 333,110 short tons of potassium salts, equivalent to 143,378 short tons of potash, according to the Department of Commerce. This indicated an increase of 133 per cent in gross weight and 131 per cent in potash content over 1933. Sales of potash salts last year totaled 325,481 tons with a potash content of 139,067 tons.

Members of the linseed oil trade have been interested in reports of rapid expansion of flaxseed production in the Imperial Valley in California. Only 300 acres were planted in 1932 with an increase to 11,500 acres in 1933 and it is reported that a jump to 50,000 acres will be made this Fall—the planting season being in the Fall with harvesting beginning a little before May 1. The most important feature of this development is found in the high yields per acre with the average running in excess of 20 bu. High-yielding seed was imported from India to start this project.

## CHEM. & MET. Weighted Index of CHEMICAL PRICES

Base = 100 for 1927

This month	88.46
Last month	88.93
May, 1933	84.80
May, 1932	85.44

A check to the upward swing of prices resulted from trading during the past month. Naval stores and specialties were prominent among the commodities which sold at lower figures. Basic chemicals were steady in price.

### Production and Consumption Data for Chemical-Consuming Industries

	March, 1934	March, 1933	Jan.- March, 1934	Jan.- March, 1933	Per Cent of Gain Jan.- March 1934
<b>Production</b>					
Arsenic, crude, tons	1,245	933	3,547	2,783	27.5
Arsenic, refined, tons	743	1,049	2,299	3,577	35.7*
Automobiles, no.	335,993	118,002	732,463	354,977	106.3
Byproduct coke, 1,000 tons	2,969	1,666	7,938	5,090	55.9
Cellulose-acetate plastics, sheets, rods, tubes, 1,000 lb.	405	119	1,199	429	179.5
Nitro-cellulose plastics, sheets, rods, tubes, 1,000 lb.	1,435	535	3,535	1,712	106.5
Glass containers, 1,000 gr.	2,920	1,704	8,290	4,925	68.3
Plate glass, 1,000 sq. ft.	9,927	4,881	24,975	16,025	55.9
Cottonseed oil, crude, 1,000 lb.	112,547	116,063	394,698	388,577	1.6
Cottonseed oil, refined, 1,000 lb.	126,978	108,775	360,719	333,916	8.0
Linseed oil, 1,000 lb.			97,452	79,595	22.4
Pyroxylin spread, 1,000 lb.	5,199	2,333	13,760	6,828	101.5
Steel barrels, no.	620,439	373,340	1,804,682	935,296	93.9
Sulphuric acid produced in fertilizer trade, tons	132,549	79,328	415,975	293,771	41.6
Rosin, wood, bbl.	43,753	26,597	139,716	83,368	67.6
Turpentine, wood, bbl.	7,279	4,255	23,141	13,405	72.6
Rubber reclaimed, tons	10,790	3,617	28,962	12,903	124.5
<b>Consumption</b>					
Cotton, 1,000 bales	544	495	1,530	1,406	8.8
Silk, bales	44,080	38,934	124,043	117,803	5.3
Wool, 1,000 lb.	36,119	24,943	106,435	93,731	13.5
Explosives, sales, 1,000 lb.	27,725	16,179	81,813	50,660	61.5
Paint, varnish, lacquer, sales, \$1,000	23,193	13,579	61,553	36,520	68.5
Sulphuric acid in fertilizer trade, tons	133,983	76,573	444,719	266,089	67.1

\*Per cent of decline.

# CURRENT PRICES

The following prices refer to round lots in the New York market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to May 14.

## Industrial Chemicals

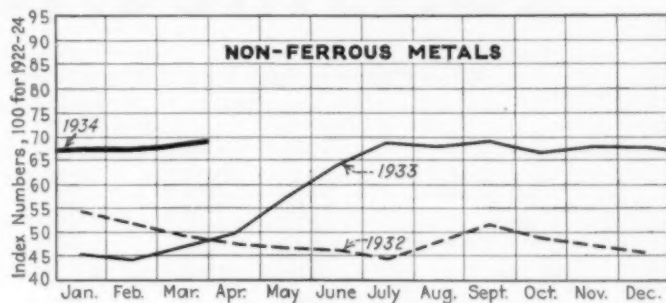
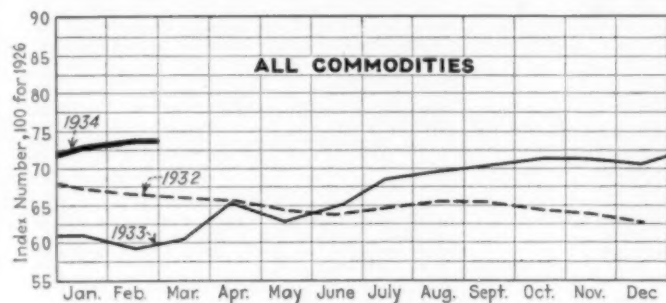
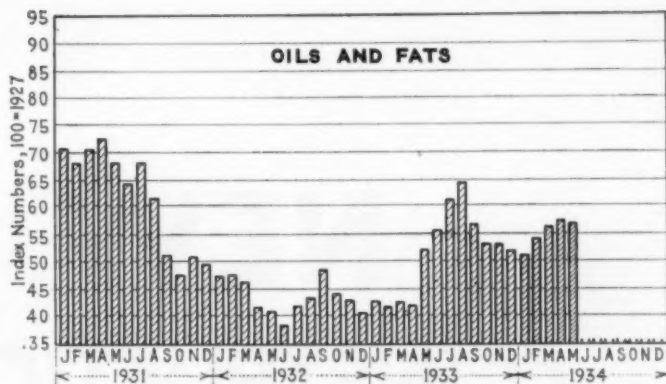
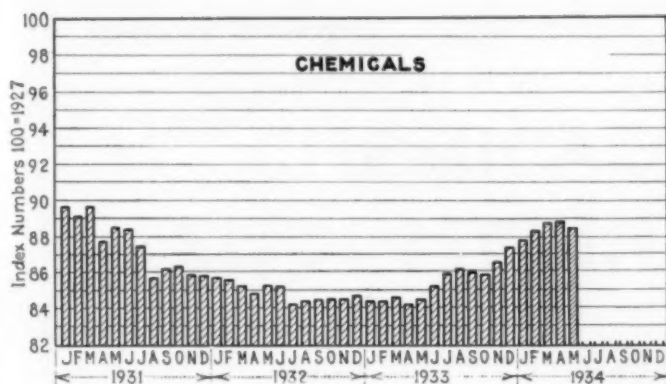
	Current Price	Last Month	Last Year
Acetone, drums, lb.	\$0.11 - \$0.11	\$0.11 - \$0.11	\$ .05 - \$0.05
Acid, acetic, 28%, bbl., cwt.	2.90 - 3.15	2.90 - 3.15	2.65 - 2.90
Glacial 99%, drums.	10.02 - 10.27	10.02 - 10.27	9.14 - 9.39
U. S. P. reagent, c'by.	10.52 - 10.77	10.52 - 10.77	9.64 - 9.89
Boric, bbl., lb.	.04 - .05	.04 - .05	.04 - .05
Boric, kegs, lb.	.28 - .31	.28 - .31	.29 - .31
Formic, bbl., lb.	.11 - .11	.11 - .11	.10 - .11
Gallie, tech., bbl., lb.	.60 - .65	.60 - .65	.50 - .55
Hydrofluoric 30% carb. lb.	.07 - .07	.07 - .07	.06 - .07
Lactic, 44%, tech. light, bbl., lb.	.11 - .12	.11 - .12	.11 - .12
22%, tech., light, bbl., lb.	.06 - .06	.05 - .06	.05 - .06
Muriatic, 18% tanks, cwt.	1.00 - 1.10	1.00 - 1.10	1.00 - 1.10
Nitric, 36% carboys, lb.	.05 - .05	.05 - .05	.05 - .05
Oleum, tanks, wks. ton.	18.50 - 20.00	18.50 - 20.00	18.50 - 20.00
Oxalic, crystals, bbl., lb.	.11 - .12	.11 - .12	.11 - .12
Phosphoric, tech., c'by., lb.	.09 - .10	.09 - .10	.08 - .09
Sulphuric, 60% tanks, ton.	11.00 - 11.50	11.00 - 11.50	11.00 - 11.50
Tannic, tech., bbl., lb.	15.50 - 15.50	15.50 - 15.50	15.50 - 15.50
Tartaric, powd., bbl., lb.	.23 - .35	.23 - .35	.23 - .35
Tungstic, bbl., lb.	.26 - .26	.26 - .26	.20 - .21
Alcohol, ethyl, 190 p'l, bbl., gal.	1.40 - 1.50	1.40 - 1.50	1.40 - 1.50
Alcohol, Butyl, tanks, lb.	4.15 - 4.15	4.15 - 4.15	2.53 - 2.53
Alcohol, Amyl	.095 - .095	.095 - .095	.095 - .095
From Pentane, tanks, lb.	.15 - .15	.15 - .15	.143 - .143
Denatured, 190 proof			
No. 1 special dr., gal.	.375 - .375	.346 - .346	.344 - .344
No. 5, 188 proof, dr., gal.	.33 - .33	.34 - .34	.38 - .38
Alum, ammonia, lump, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Chrome, bbl., lb.	.04 - .05	.04 - .05	.04 - .05
Potash, lump, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Aluminium sulphate, com., bags, cwt.	1.35 - 1.50	1.35 - 1.50	1.25 - 1.40
Iron free, bz., cwt.	1.90 - 2.00	1.90 - 2.00	1.90 - 2.00
Aqua ammonia, 26%, drums lb.	.02 - .03	.02 - .03	.02 - .03
tanks, lb.	.02 - .02	.02 - .02	.02 - .02
Ammonia, anhydrous, cyl., lb.	.15 - .16	.15 - .16	.15 - .15
tanks, lb.	.04 - .04	.04 - .04	.05 - .05
Ammonium carbonate, powd.			
tech., casks, lb.	.08 - .12	.08 - .12	.08 - .12
Sulphate, wks. cwt.	1.25 - 1.25	1.25 - 1.25	1.15 - 1.15
Amylacetate tech., tanks, lb., gal	.14 - .14	.14 - .14	.135 - .135
Antimony Oxide, bbl., lb.	.08 - .09	.08 - .10	.07 - .08
Arsenic, white, powd., bbl., lb.	.04 - .04	.04 - .04	.04 - .04
Red, powd., kegs, lb.	.15 - .15	.15 - .15	.09 - .10
Barium carbonate, bbl., ton.	56.50 - 58.00	56.50 - 58.00	56.50 - 58.00
Chloride, bbl., ton.	74.00 - 75.00	74.00 - 75.00	63.00 - 65.00
Nitrate, cask, lb.	.08 - .09	.08 - .09	.07 - .07
Blanc fixe, dry, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Bleaching powder, f.o.b., wks. drums, cwt.	1.85 - 2.00	1.85 - 2.00	1.75 - 2.00
Borax, grain, bags, ton.	40.00 - 45.00	40.00 - 45.00	40.00 - 45.00
Bromine, ca., lb.	.36 - .38	.36 - .38	.36 - .38
Calcium acetate, bags	3.00 - 3.00	3.00 - 3.00	2.50 - 2.50
Arsenate, dr., lb.	.05 - .07	.07 - .08	.05 - .06
Carbide, drums, lb.	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., wks. ton.	17.50 - 17.50	17.50 - 17.50	18.00 - 18.00
flake, dr., wks. ton.	19.50 - 19.50	19.50 - 19.50	21.00 - 21.00
Phosphate, bbl., lb.	.07 - .08	.07 - .08	.07 - .08
Carbon bisulphide, drums, lb.	.05 - .06	.05 - .06	.05 - .06
Tetrachloride drums, lb.	.05 - .06	.05 - .06	.06 - .07
Chlorine, liquid, tanks, wks. lb.	.0185 - .0185	.0185 - .0185	.01 - .01
Cylinders	.05 - .06	.05 - .06	.05 - .06
Cobalt oxide, cans, lb.	1.35 - 1.40	1.35 - 1.40	1.25 - 1.35

	Current Price	Last Month	Last Year
Copperas, bgs., f.o.b. wks. ton.	14.00 - 15.00	14.00 - 15.00	14.00 - 15.00
Copper carbonate, bbl., lb.	.08 - .16	.08 - .16	.07 - .16
Cyanide, tech., bbl., lb.	.39 - .44	.39 - .44	.39 - .44
Sulphate, bbl., cwt.	3.85 - 4.00	3.85 - 4.00	3.25 - 3.50
Cream of tartar, bbl., lb.	.19 - .20	.18 - .19	.14 - .15
Diethylene glycol, dr., lb.	.14 - .16	.14 - .16	.14 - .16
Epsom salt, dom., tech., bbl., cwt.	2.10 - 2.15	2.10 - 2.15	1.70 - 2.00
Imp., tech., bags, cwt.	2.00 - 2.10	2.00 - 2.10	1.15 - 1.25
Ethyl acetate, drums, lb.	.08 - .08	.08 - .08	.08 - .08
Formaldehyde, 40%, bbl., lb.	.06 - .07	.06 - .07	.06 - .07
Furfural, dr., contract, lb.	.10 - .17	.10 - .17	.10 - .17
Fusel oil, crude, drums, gal.	.75 - .75	.75 - .75	1.10 - 1.20
Refined, dr., gal.	1.25 - 1.30	1.25 - 1.30	1.80 - 1.90
Glauber's salt, bags, cwt.	1.00 - 1.10	1.00 - 1.10	1.00 - 1.10
Glycerine, c.p., drums, extra, lb.	.12 - .13	.12 - .13	.10 - .10
Lead:			
White, basic carbonate, dry casks, lb.	.06 - .06	.06 - .06	.06 - .06
White, basic sulphate, ack., lb.	.06 - .06	.06 - .06	.06 - .06
Red, dry, ack., lb.	.06 - .06	.06 - .06	.07 - .07
Lead acetate, white crys., bbl., lb.	.10 - .11	.10 - .11	.10 - .11
Lead arsenate, powd., bbl., lb.	.09 - .13	.09 - .13	.09 - .13
Lime, chem., bulk, ton.	8.50 - 8.50	8.50 - 8.50	8.50 - 8.50
Litharge, powd., csk, lb.	.06 - .06	.06 - .06	.05 - .05
Lithophone, bags, lb.	.04 - .05	.04 - .05	.04 - .05
Magnesium carb., tech., bags, lb.	.06 - .06	.06 - .06	.05 - .06
Methanol, 95%, tanks, gal.	.33 - .33	.33 - .33	.33 - .33
97%, tanks, gal.	.34 - .34	.34 - .34	.34 - .34
Synthetic, tanks, gal.	.35 - .35	.35 - .35	.35 - .35
Nickel salt, double, bbl., lb.	.11 - .12	.11 - .12	.11 - .11
Orange mineral, csk, lb.	.10 - .10	.10 - .10	.09 - .09
Phosphorus, red, cases, lb.	.45 - .46	.45 - .46	.42 - .44
Yellow, cases, lb.	.28 - .32	.28 - .32	.28 - .32
Potassium bichromate, casks, lb.	.07 - .08	.07 - .08	.07 - .08
Carbonate, 80-85%, calc. csk, lb.	.07 - .07	.07 - .07	.05 - .06
Chlorate, powd., lb.	.09 - .10	.09 - .10	.08 - .08
Hydroxide (c'etiepotash) dr., lb.	.07 - .07	.07 - .07	.06 - .06
Muriate, 80% bgs., ton.	31.90 - 31.90	37.15 - 37.15	37.15 - 37.15
Nitrate, bbl., lb.	.05 - .06	.05 - .06	.05 - .06
Permanganate, drums, lb.	.18 - .19	.18 - .19	.16 - .16
Prussiate, yellow, casks, lb.	.18 - .19	.18 - .19	.16 - .17
Sal ammoniac, white, casks, lb.	.04 - .05	.04 - .05	.04 - .05
Salsoda, bbl., cwt.	1.00 - 1.05	1.00 - 1.05	.90 - .95
Salt cake, bulk, ton.	13.00 - 15.00	13.00 - 15.00	13.00 - 15.00
Soda ash, light, 58%, bags, contract, cwt.	1.23 - 1.23	1.23 - 1.23	1.15 - 1.15
Dense, bags, cwt.	1.25 - 1.25	1.25 - 1.25	1.17 - 1.17
Soda, caustic, 76%, solid, drums, contract, cwt.	2.60 - 3.00	2.60 - 3.00	2.50 - 2.75
Acetate, works, bbl., lb.	.04 - .05	.04 - .05	.04 - .05
Bicarbonate, bbl., cwt.	1.85 - 2.00	1.85 - 2.00	1.85 - 2.00
Bichromate, casks, lb.	.05 - .06	.05 - .06	.04 - .05
Bisulphate, bulk, ton.	14.00 - 16.00	14.00 - 16.00	14.00 - 16.00
Bisulphite, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Chlorate, kegs, lb.	.06 - .06	.06 - .06	.05 - .07
Chloride, tech., ton.	12.00 - 14.75	12.00 - 14.75	12.00 - 14.00
Cyanide, cases, dom., lb.	.15 - .16	.15 - .16	.15 - .16
Fluoride, bbl., lb.	.07 - .08	.07 - .08	.07 - .08
Hyposulphite, bbl., lb.	2.40 - 2.50	2.40 - 2.50	2.40 - 2.50
Metasilicate, bbl., cwt.	3.25 - 3.40	3.25 - 3.40	3.25 - 3.40
Nitrate, bags, cwt.	1.35 - 1.35	1.35 - 1.35	1.345 - 1.345
Nitrite, casks, lb.	.07 - .08	.07 - .08	.07 - .08
Phosphate, dibasic, bbl., lb.	.02 - .023	.02 - .023	.018 - .02
Prussiate, vel. drums, lb.	.11 - .12	.11 - .12	.11 - .12
Silicate (40% dr.) wks. cwt.	.80 - .85	.80 - .85	.70 - .75
Sulphide, fused, 60-62%, dr., lb.	.02 - .03	.02 - .03	.02 - .03
Sulphite, cys., bbl., lb.	.02 - .02	.02 - .02	.03 - .03
Sulphur, crude at mine, bulk, ton	18.00 - 18.00	18.00 - 18.00	18.00 - 18.00
Chloride, dr., lb.	.03 - .04	.03 - .04	.03 - .04
Dioxide, cyl., lb.	.07 - .07	.07 - .07	.06 - .07
Flour, bag, cwt.	1.60 - 3.00	1.55 - 3.00	1.55 - 3.00
Tin Oxide, bbl., lb.	.58 - .58	.57 - .57	.37 - .37
Crystals, bbl., lb.	.40 - .40	.40 - .40	.29 - .29
Zinc chloride, gran., bbl., lb.	.05 - .06	.05 - .06	.06 - .06
Carbonate, bbl., lb.	.09 - .11	.09 - .11	.10 - .11
Cyanide, dr., lb.	.38 - .42	.38 - .42	.38 - .42
Dust, bbl., lb.	.07 - .07	.07 - .07	.04 - .05
Zinc oxide, lead free, bag, lb.	.06 - .06	.06 - .06	.05 - .05
5% lead sulphate, bags, lb.	.06 - .06	.06 - .06	.05 - .05
Sulphate, bbl., cwt.	3.00 - 3.25	3.00 - 3.25	3.00 - 3.25

## Oils and Fats

	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl., lb.	\$0.09 - \$0.10	\$0.09 - \$0.10	\$0.08 - \$0.09
Chinawood oil, bbl., lb.	.08 - .08	.08 - .08	.05 - .05
Cocoonut oil, Ceylon, tanks, N. Y. lb.	.02 - .02	.02 - .02	.03 - .03
Corn oil crude, tanks, (f.o.b. mill), lb.	.04 - .04	.04 - .04	.04 - .04
Cottonseed oil, crude (f.o.b. mill), tanks, lb.	.04 - .04	.04 - .04	.04 - .04
Linseed oil, raw ear lots, bbl., lb.	.09 - .09	.09 - .09	.08 - .08
Palm, Lagos, casks, lb.	.03 - .03	.03 - .03	.03 - .03
Palm Kernel, bbl., lb.	.04 - .04	.04 - .04	.04 - .04
Peanut oil, crude, tanks (mill), lb.	.05 - .05	.05 - .05	.04 - .04
Rapeseed oil, refined, bbl., gal.	.39 - .40	.42 - .43	.40 - .42
Soya bean, tank, lb.	.06 - .06	.06 - .06	.05 - .05
Sulphur (olive foots), bbl., lb.	.07 - .07	.06 - .06	.05 - .05
Cod, Newfoundland, bbl., gal.	nom. - nom.	nom. - nom.	.23 - .24
Menhaden, light pressed, bbl., lb.	.05 - .05	.05 - .05	.04 - .04
Crude, tanks (f.o.b. factory), gal.	.20 - .20	.20 - .20	.10 - .10
Grease, yellow, loose, lb.	.03 - .03	.03 - .03	.03 - .03
Oil stearine, lb.	.05 - .05	.05 - .05	.05 - .05
Red oil, distilled, d.p. bbl., lb.	.07 - .07	.07 - .07	.06 - .06
Tallow, extra, loose, lb.	.03 - .03	.03 - .03	.03 - .03





### Coal-Tar Products

	Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl., lb.	\$0.60 - \$0.65	\$0.60 - \$0.65	\$0.60 - \$0.62
Refined, bbl., lb.	.80 - .85	.80 - .85	.80 - .85
Alpha-naphthylamine, bbl., lb.	.32 - .34	.32 - .34	.32 - .34
Aniline oil, drums, extra, lb.	.14 - .15	.14 - .15	.14 - .15
Aniline salts, bbl., lb.	.24 - .25	.24 - .25	.24 - .25
Benzaldehyde, U.S.P., dr., lb.	1.10 - 1.25	1.10 - 1.25	1.10 - 1.25
Benzidine base, bbl., lb.	.65 - .67	.65 - .67	.65 - .67
Benzoic acid, U.S.P., kgs, lb.	.48 - .52	.48 - .52	.48 - .52
Benzyl chloride, tech., dr., lb.	.30 - .35	.30 - .35	.30 - .35
Benzol, 90%, tanks, works, gal.	.19 - .20	.19 - .20	.22 - .23
Beta-naphthol, tech., drums, lb.	.22 - .24	.22 - .24	.22 - .24
Cresol, U.S.P., dr., lb.	.11 - .11	.11 - .11	.10 - .11
Cresylic acid, 97%, dr., wks., gal.	.50 - .51	.50 - .51	.42 - .45
Diethylaniline, dr., lb.	.55 - .58	.55 - .58	.55 - .58
Dinitrophenol, bbl., lb.	.29 - .30	.29 - .30	.29 - .30
Dinitrotoluen, bbl., lb.	.16 - .17	.16 - .17	.16 - .17
Dip oil 25% dr., gal.	.23 - .25	.23 - .25	.23 - .25
Diphenylamine, bbl., lb.	.38 - .40	.38 - .40	.38 - .40
H-acid, bbl., lb.	.65 - .70	.65 - .70	.65 - .70
Naphthalene, flake, bbl., lb.	.06 - .07	.06 - .07	.04 - .05
Nitrobenzene, dr., lb.	.08 - .09	.08 - .09	.08 - .10
Para-nitraniline, bbl., lb.	.51 - .55	.51 - .55	.51 - .55
Phenol, U.S.P., drums, lb.	.14 - .15	.14 - .15	.14 - .15
Picric acid, bbl., lb.	.30 - .40	.30 - .40	.30 - .40
Pyridine, dr., gal.	1.10 - 1.15	1.10 - 1.15	.90 - .95
Resorcinol, tech., kgs, lb.	.65 - .70	.65 - .70	.65 - .70
Salicylic acid, tech., bbl., lb.	.40 - .42	.40 - .42	.40 - .42
Solvent naphtha, w.w., tanks, gal.	.26 - .26	.26 - .26	.26 - .26
Tolidine, bbl., lb.	.88 - .90	.88 - .90	.88 - .90
Toluene, tanks, works, gal.	.30 - .30	.30 - .30	.30 - .30
Xylene, com., tanks, gal.	.26 - .26	.26 - .26	.26 - .26

### Miscellaneous

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl., ton...	\$22.00 - \$25.00	\$22.00 - \$25.00	\$22.00 - \$25.00
Casein, tech., bbl., lb.	.12 - .13	.11 - .13	.08 - .10
China clay, dom., f.o.b. mine, ton	8.00 - 20.00	8.00 - 20.00	8.00 - 20.00
Dry colors:			
Carbon gas, black (wks.), lb.	.04 - .20	.04 - .20	.02 - .20
Prussian blue, bbl., lb.	.35 - .37	.35 - .37	.35 - .36
Ultramarine blue, bbl., lb.	.06 - .32	.06 - .32	.06 - .32
Chrome green, bbl., lb.	.26 - .27	.26 - .27	.27 - .30
Carmine red, tins, lb.	4.00 - 4.40	4.00 - 4.40	3.90 - 4.50
Para toner, lb.	.80 - .85	.80 - .85	.75 - .80
Vermilion, English, bbl., lb.	1.60 - 1.63	1.60 - 1.63	1.10 - 1.30
Chrome yellow, C. P., bbl., lb.	.15 - .16	.15 - .16	.15 - .15
Feldspar, No. 1 (f.o.b. N.C.), ton	6.50 - 7.50	6.50 - 7.50	6.50 - 7.50
Graphite, Ceylon, lump, bbl., lb.	.07 - .08	.07 - .08	.07 - .08
Gum copal Congo, bags, lb.	.09 - .10	.08 - .09	.06 - .08
Manila, bags, lb.	.09 - .10	.09 - .10	.16 - .17
Damar, Batavia, cases, lb.	.15 - .16	.15 - .16	.16 - .16
Kauri No. 1 cases, lb.	.20 - .25	.20 - .25	.45 - .48
Kieselguhr (f.o.b. N.Y.), ton	50.00 - 55.00	50.00 - 55.00	50.00 - 55.00
Magnesite, calc, ton	50.00 - .00	50.00 - .00	40.00 - .00
Pumice stone, lump, bbl., lb.	.05 - .07	.05 - .08	.05 - .07
Imported, cases, lb.	.03 - .40	.03 - .40	.03 - .35
Rosin, H., bbl.	6.05 - .00	6.25 - .00	4.75 - .00
Turpentine, gal.	.56 - .58	.58 - .58	.48 - .48
Shellac, orange, fine, bags, lb.	.36 - .37	.28 - .29	.19 - .20
Bleached, bonedry, bags, lb.	.35 - .36	.29 - .31	.18 - .19
T. N. bags, lb.	.28 - .29	.21 - .22	.08 - .09
Soapstone (f.o.b. Vt.), bags, ton	10.00 - 12.00	10.00 - 12.00	10.00 - 12.00
Talc, 200 mesh (f.o.b. Vt.), ton	8.00 - 8.50	8.00 - 8.50	8.00 - 8.50
300 mesh (f.o.b. Ga.), ton	7.50 - 10.00	7.50 - 10.00	7.50 - 11.00
225 mesh (f.o.b. N. Y.), ton	13.75 - .00	13.75 - .00	13.75 - .00

## INDUSTRIAL NOTES

THE PFAUDLER CO., Rochester, N. Y., has moved its New York office to the McGraw-Hill Building, 330 West 42nd St. W. E. Gray, Jr. is manager of the office assisted by J. J. Hickey, S. A. Smith, and H. J. Grieve.

THE IRONTON FIRE BRICK CO., Ironton, Ohio, has appointed Glencoy Specialties Co., Zanesville, Ohio, as representatives in eastern Ohio, western Pennsylvania, and part of West Virginia.

AMERICAN CYANAMID & CHEMICAL CORP., New York, has opened a department to import and deal in crude rubber with Bancroft W. Henderson in charge.

THE R. & H. CHEMICALS DEPARTMENT OF E. I. du Pont de Nemours & Co., Wilmington, has appointed the following distributors for "Arctic" brand methyl chloride: National Ammonia Co., Philadelphia; Mary-

land Chemical Co., Baltimore; Merkel Bros. & Co., Cincinnati; Eaton-Clark Co., Detroit; Chemical Distributors, Inc., Chicago; Enoch Sales Co., Fernwood, Miss.; G. P. Robins & Co., St. Louis; Thompson-Hayward Chemical Co., Kansas City; Hunzicker Bros. Co., Oklahoma City; Denver Fire Clay Co., Salt Lake City; and L. H. Butcher & Co., San Francisco.

HEVI DUTY ELECTRIC CO., Milwaukee, has appointed L. A. Shea of the main office, district representative for Ohio with headquarters at 5005 Euclid Ave., Cleveland.

ANTHOR TESTING INSTRUMENT CO., INC., has moved from 309 Johnson St. to 4-10 Leo Place, Brooklyn.

STEPHENS-ADAMSON MFG. CO., Aurora, Ill., has reopened sales engineering offices at Pittsburgh and at Huntington, W. Va. The Pittsburgh office at 1206 Gulf Building is in charge of Harry W. Banbury and

D. W. Allen is conducting the Huntington office.

TIMKEN ROLLER BEARING CO., has moved its Pittsburgh office to its new building at 414-416 North Craig St.

MOORHEAD-REITMEYER CO., INC., Pittsburgh, has moved its sales offices to the Columbia Building, 4th Ave. and Wood St.

HAROLD B. VOLLRATH, consultant on chemical engineering, has moved to 350 Madison Ave., New York.

REPUBLIC STEEL CORP., Youngstown, Ohio, has appointed Barde Steel Co. and the Doran Co., both of Seattle, as distributors of Enduro stainless steel.

THE GENERAL ENGINEERING CO., metallurgical engineers, Salt Lake City, has opened an office at 50 Broad St., New York, with E. S. Tompkins in charge.

# NEW CONSTRUCTION

## Where Plants Are Being Built in Process Industries

	Current Projects		Cumulative to Date	
	Proposed Work and Bids	Contracts Awarded	Proposed Work and Bids	Contracts Awarded
New England.....	\$150,000	\$380,000	\$887,000	\$527,000
Middle Atlantic.....	178,000	167,000	2,094,000	2,032,000
Southern.....	108,000	150,000	11,567,000	1,255,000
Middle West.....	860,000	201,000	2,554,000	1,605,000
West of Mississippi.....	70,000	.....	14,413,000	331,000
Far West.....	616,000	68,000	1,633,000	1624,000
Canada.....	633,000	850,000	2,191,000	.....
Total.....	\$2,615,000	\$1,816,000	\$35,339,000	\$6,374,000

## PROPOSED WORK BIDS ASKED

**Chemical Plant**—American Treibach Chemical Works, Inc., C. Ganz, Pres., 3303 Highland Ave., Niagara Falls, N. Y., plans the construction of a plant for the manufacture of metallic cerium and other rare metal products. The company eventually plans to manufacture radium. Estimated cost \$100,000.

**Chemical Plant**—Soda Lumina Chemical Corporation of Canada, Ltd., N. J. Grean, Mgr., Eastview, Ont., is having plans prepared for an addition to its plant for the manufacture of silica. Estimated cost \$35,000.

**Chemical Plant**—Wall Chemicals, Ltd., Albert F. Wall, Gen. Mgr., 1059 West Grand Blvd., Detroit, Mich., plans to construct a plant at Windsor, Ont., Can. Estimated cost \$40,000.

**Pharmaceutical Plant**—The Upjohn Co., Kalamazoo, Mich., is having preliminary plans prepared for the construction of a 10 story factory and office building, including a power plant. Estimated cost \$200,000.

**Physics and Chemistry Building**—Wellesley College, Wellesley, Mass., plans the construction of a 4 story Physics and Chemistry Building. Charles Z. Klauder, 1429 Walnut St., Philadelphia, Pa., is architect. Estimated cost \$150,000.

**Chemistry Building**—University of California, Westwood, Los Angeles, Calif., will soon take bids for the construction of a Chemistry Building. H. J. Brunner, Sharon Bldg., San Francisco, structural engineer; Hunter & Hudson, 41 Sutter St., San Francisco, mechanical engineers. Estimated cost \$300,000.

**Distillery**—Burks Spring Distilling Co., c/o L. C. Roberts, Loretto, Ky., plans to rehabilitate and build addition to distillery at Loretto, Ky. Estimated cost with equipment \$28,000.

**Distillery**—Burlington Distillery Co., Burlington, N. J., plans to remodel and build addition to plant of former Burlington Industrial Alcohol Co. Estimated cost with equipment \$50,000.

**Distillery**—L. G. Ham, et al, c/o Hunt-Mirk Co., Engrs., 141 Second St., San Francisco, Calif., is having plans prepared for a 1 story distillery at Benicia, Calif. Estimated cost \$60,000.

**Distillery**—New England Distilling Co., Covington, Ky., plans to build an addition to its plant. Estimated cost \$30,000.

**Distillery**—Republic Distillers, Inc., c/o Col. W. A. Thomson, 370 Lexington Ave., New York, N. Y., is having plans prepared by Carl

J. Kiefer, Engr., Schmidt Bldg., Cincinnati, O., for reconditioning plant of H. A. Thierman at Louisville, Ky., for its own use. Federal permit has been granted for work. Estimated cost \$50,000.

**Gas Plant**—City, c/o Mayor, Bushnell, Ill., is having plans prepared by McBride Gas Engineering Co., c/o J. A. McBride Mechanical Equipment Co., 2815 Locust St., St. Louis, Mo., for the construction of a gas plant and distribution system. Estimated cost \$80,000.

**Gas Plant**—City, c/o Mayor, Sullivan, Ill., is having plans prepared by McBride Gas Engineering Co., c/o J. A. McBride Mechanical Equipment Co., 2815 Locust St., St. Louis, Mo., for the construction of a gas plant and distribution system. Estimated cost \$79,500.

**Gas Plant**—City, I. V. Backlegge, Chk., Security Bldg., Washington, Mo., plans the construction of a gas plant and distribution system. Estimated cost \$70,000.

**Oil Refinery**—British American Oil Co., Ltd., Royal Bank Bldg., Toronto, Ont., plans to modernize and enlarge its Western Canada plants. Estimated cost \$500,000.

**Oil Refinery**—Crew Levick Co., subsidiary of Cities Service Co., 60 Wall St., New York, N. Y., Titusville, Pa., plans extension and improvements to its refinery here.

**Lubricating Plant**—Penant Oil & Grease Co., Santa Fe Ave., Los Angeles, Calif., is having plans prepared by its engineering department for an oil storage terminal at Parr Terminal.

**Paper Products Plant**—Gair Co. of Canada, Ltd., Toronto, Ont., manufacturer of paper, paperboard, etc., plans to establish a plant here.

**Rubber Factory**—Ideal Rubber Co., Ltd., Eastview, Ont., plans the construction of a factory for the manufacture of rubber goods on Wilton Ave. Estimated cost \$30,000.

**Smelting Plant**—American Smelting & Refining Co., W. J. O'Connor, Engr., Salt Lake City, Utah, plans improvements to its smelting plant at Garfield, Utah. Estimated cost \$150,000.

**Cyanide Mill**—United Verde Copper Co., Jerome, Ariz., plans to construct a cyanide mill on its property here. R. E. Tally, Vice-Pres., is in charge of operations. Estimated cost \$50,000.

**Carbide Plant**—Union Carbide & Carbon Co., 30 East 42nd St., New York, N. Y., has purchased a site at Whiting, Ind., and plans to construct a plant. Estimated cost \$500,000.

**Roofing Plant**—American Asphalt Roofing Co., 1674 Beck St., Salt Lake City, Utah, King G. Clawson, Mgr., plans to remodel its plant here.

## CONTRACTS AWARDED

**Process Plant**—Franklin Process Co., 564 Eddy St., Providence, R. I., awarded contract for altering and building 3 story 84x84 ft. addition to plant to Bowerman Bros., 70 Bath St., Providence, R. I. Estimated cost exceeds \$28,000.

**Glue House**—Krebs Pigment & Color Co., 2001 Benhill Ave., Baltimore, Md., awarded contract for 3 story glue house and 1 story pump house to W. E. Bickerton Construction Co., 515 Cathedral St., Baltimore.

**Laboratory**—Commonwealth of Massachusetts, Department of Mental Diseases, State House, Boston, Mass., awarded contract for laboratory and mortuary building at Boston State Hospital, Dorchester, to Matthew Cummings Co., 43 Tremont St., Boston. Estimated cost \$54,400.

**Kilns**—Homer Laughlin China Co., Newell, W. Va., awarded contract for two circular continuous kilns for firing of bisque and glost ware and re-equipping plant No. 5 with latest type machinery, to Allied Engineering Co., Columbus, O. Estimated cost \$150,000.

**Paper Plant**—Neenah Paper Co., Commercial St., Neenah, Wis., awarded contract for plant and storage building to C. R. Meyer & Sons Co., 50 State St., Oshkosh, Wis. Estimated cost \$30,000.

**Oil Refinery**—Andrews Oil Co., Kaukauna, Wis., awarded contract for 1 story, 47x50 ft. plant and service shop to J. N. Foeller, Decker Ave., Green Bay, Wis.

**Rubber Factory**—Oliver Tire & Rubber Co., 4343 San Pablo Ave., Emeryville, Calif., awarded contract for 1 story, 50x100 ft. factory addition, to F. J. Early, 1629 Telegraph Ave., Oakland.

**Tannery**—Badger State Tanning Co., 108 Illinois Ave., Sheboygan, Wis., awarded contract for conveyor and washing building addition to tannery, to Martin Leiny, 23016 North 6th St., Sheboygan.

**Warehouse**—Lawless Paper Mills, Inc., East Rochester, N. Y., awarded contract for warehouse at plant to Gorsline & Swan Construction Co., 96 Pearl St., Rochester, \$28,500.

**Warehouse**—Merrimac Chemical Co., Inc., Chemical Lane, Everett, Mass., awarded contract for a 1 story, 62x140 ft. warehouse, to W. M. Bailey Co., 88 Broad St., Boston. Estimated cost \$28,000.

**Warehouse, Etc.**—Atlantic Refining Co., 260 South Broad St., Philadelphia, Pa., awarded contract for excavating for steel storage tanks, office, warehouse and garage, on Lyell Ave., Rochester, N. Y., to F. J. Hines, 79 Monterey Rd., Rochester, N. Y. Total estimated cost \$75,000.

**Carbide Plant**—Union Carbide & Carbon Co., Niagara Falls, N. Y., awarded contract for building on 47th St. to house metallurgical division of companies' research laboratories which will be moved from Long Island City, N. Y., to Laur & Mack, 1400 College Ave., Niagara Falls, N. Y.

**Laboratory**—Ohio College of Chiropractic, 2057 Cornell Rd., Cleveland, O., awarded contract for laboratory building, to Sam W. Emerson Co., 1836 Euclid Ave., Cleveland. Estimated cost \$40,000.

**Distillery**—Old Colonial Distilleries, Detroit, Mich., awarded contract for remodeling and building additions to distillery at Battle Creek, Mich., to Conrad Keller Co., 4628 Moran St., Detroit. Estimated cost \$75,000.

**Salt Plant**—Warwick Salt Co., Boris Witkov, Genl. Mgr., Warwick, via Watford P.O., Ont., is building a 1 story brick addition to its plant. Contract for steel salt pans has been awarded to London Structural Steel Co., Burslem St., London. The company also plans to purchase other equipment. Estimated cost \$50,000.

**Pulp Factory**—New Haven Pulp & Board Co., 259 East St., New Haven, Conn., awarded contract for addition to factory on East St. to H. Wales Lines Co., 134 State St., Meriden. Estimated cost \$42,000.

**Paper Factory**—Western Waxed Paper Co., 910 East 61st St., Los Angeles, Calif., awarded contract for 1 story, 100x150 ft. addition to factory, to Lindgren & Swinerton, 523 West 6th St., Los Angeles. Estimated cost \$40,000.

**Warehouse and Distillery**—A. & G. J. Caldwell, Inc., Newburyport, Mass., awarded contract for engineering and construction work for warehouse and distillery to Lummas Co., 50 Church St., New York, N. Y., who have sublet part of work to W. M. Bailey Co., 88 Broad St., Boston, Mass. Caisson foundations have been let to New England Foundation Co., 38 Chauncey St., Boston, Mass. Estimated cost \$200,000.

**Warehouse and Office**—Pittsburgh Plate Glass Co., 126 Liberty St., Springfield, Mass., awarded contract for warehouse and office building, to A. L. Phelps, Inc., 138 Magnolia Terrace, Springfield. Estimated cost exceeds \$28,000.

**Factory**—Canadian Industries, Ltd., P. O. Box 1260, Montreal, Que., awarded contract for factory for the manufacture of chlorine and caustic soda, to Fraser-Brace, Ltd., Montreal. Estimated cost \$800,000.